Canada Alberta

FOREST RESOURCE DEVELOPMENT AGREEMENT
ENTENTE SUR LA MISE EN VALEUR DES RESSOURCES FORESTIERES

Canada Alberta

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The Canada-Alberta Forest Resource Development Agreement is a subsidiary agreement of the Canada-Alberta Economic and Regional Development Agreement, which provides coordination and cooperation between the governments of Alberta and Canada in areas of Alberta's economic development.

The Canada-Alberta Forest Resource Development Agreement is funded equally by the governments of Canada and Alberta, from April 1, 1984, to March 31, 1989.

Its primary objectives are to ensure the long-term availability of timber supplies; to optimize timber uses; and to contribute to the growth and diversification of Alberta's economy.

The Agreement comprises three programs: Reforestation; Applied research, technology transfer and opportunity identification; and Public information, evaluation and administration. These programs are managed by a joint Directorate and are implemented by the Canadian Forestry Service and the Alberta Forest Service.

L'Entente Canada-Alberta sur la mise en valeur des ressources forestières est auxiliaire à l'Entente Canada-Alberta sur le développement économique et régional, qui vise à assurer la coordination et la coopération des deux gouvernements relativement au développement économique de l'Alberta.

L'Entente Canada-Alberta sur la mise en valeur des ressources forestières est financée à parts égales par les gouvernements du Canada et de l'Alberta, et a cours du 1er avril 1984 au 31 mars 1989.

Ses objectifs principaux sont assurer la disponibilité à long terme de réserves de bois; optimiser leur utilisation; et contribuer à la croissance et la diversification de l'économie de la province.

L'Entente comprend trois programmes: Reboisement; Recherche appliquée, transferts de connaissances techniques et relevé des occasions; et Information, évaluation et administration. Ces programmes sont gérés par un Bureau de direction conjoint, et mis en oeuvre par le Service canadien des forêts et le Service forestier de l'Alberta.

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PREPARATION OF PULPS FROM SOUND ALBERTA ASPEN AND BALSAM POPLAR BY VARIOUS PROCESSES

This is a joint publication of the Canadian Forestry Service and the Alberta Forest Service pursuant to the Canada-Alberta Forest Resource Development Agreement

ECONOTECH SERVICES LIMITED

PAUL R. THOMAS
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DISCLAIMER

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PREPARATION OF PULPS FROM SOUND ALBERTA ASPEN AND BALSAM POPLAR BY VARIOUS PROCESSES

SUMMARY

Sound Alberta aspen and balsam poplar have been subjected to a range of processes to produce the following pulps:

- Bleached kraft
- Bleached alkaline sulphite/anthraquinone
- High yield sulphite
- NSSC
- Bleached solvent (methanol)
- CTMP

The pulps have been evaluated for yield and strength characteristics.

The work has shown that these sound samples of the two species gave good quality pulps by the processes studied. Owing to the relatively novel aspects of the ASAQ and solvent pulping systems, further work is desirable.

BACKGROUND

The world's hardwood resources are being increasingly utilized for the production of pulp. Some species have found particularly good acceptance in the marketplace and notable amongst these would be European birch and Eucalyptus from such countries as Brazil, Chile and Australia. Canada also possesses a major hardwood resource and efforts to utilize it as a raw material for pulp manufacture are increasing. Many pulp mills use small quantities of hardwood combined with softwood for bleached market kraft pulp production and some mills produce bleached market kraft pulp with a high proportion of hardwood present.

Two of the major hardwoods in Alberta are trembling aspen (Populus tremuloides Michx.) and balsam poplar (Populus balsamifera L.). Of these two, trembling aspen is present in the largest quantity. An excellent description of the Alberta trembling aspen is provided in the Alberta Research Council publication "Alberta Aspen - Tomorrow's Resource Today". With increasing attention being applied to the use of these woods in Alberta, improved documentation of the potential of this wood as a raw material for pulp manufacture was required. Previous pulping studies have been carried out on aspen from various parts of North America, including work by Econotech on the Alberta aspen

resource. Two of the previous studies carried out by Econotech were: "An Evaluation of Aspen and Balsam Poplar Wood from the O'Chiese Block for the Production of Kraft Thermomechanical and Chemimechanical Pulps" prepared for Pedology Consultants in early 1982, and "The Effect of Rot and Defect on the Production, Quality and Cost of Aspen Bleached CTMP" prepared for the Alberta Research Council in early 1983. In addition, Econotech has carried out projects on the use of solvent pulping with Alberta aspen. Econotech has also evaluated the hardwood resource from elsewhere in Canada, the United States and abroad.

The above studies are always complicated by the presence of varying degrees of rot and stain in the hardwood as is the case with a large number of other hardwood and softwood forests. In promoting the utilization of their forests, the Alberta Energy and Natural Resources Department felt that it would be appropriate to evaluate samples of trembling aspen and balsam poplar by a variety of different pulping processes. All the processes would be carried out on the same sample of wood to allow inter-comparison and the wood sample used would be derived from a variety of forest regions to provide a representative sample. The first step would be to derive this information for sound samples of trembling aspen and balsam poplar.

The above approach would allow the production of "technical data sheets" for each species and for the different processes to be studied. There would be no complications of trying to compare data from different studies and with woods of different quality.

OBJECTIVES

The principal objective of this work was to produce information for use in the production of technical data sheets on the use of Alberta trembling aspen and balsam poplar as pulp raw materials. More specifically, the work was designed to identify a) typical fibre characteristics, including fibre length, cell wall thickness, coarseness and wood density; b) key aspects of the pulping processes used and responses of aspen and balsam poplar to them in terms of yield; c) ease of pulping relative to chemical requirement and reject material and quality of unbleached pulp; d) key aspects of bleaching processes required for the pulp; e) quality of the bleached pulps with emphasis on end-use potential. In general, the project was also required to identify any deficiencies in the present knowledge of the Alberta aspen and balsam poplar resource as a pulping fibre and to recommend future courses of action pertaining to the development of relevant data bases for exploitation of these raw materials for the pulp industry.

The following processes were to be evaluated:

Bleached kraft
Bleached alkaline sulphite/anthraquinone
High yield sulphite
NSSC
Bleached solvent (methanol)
CTMP

RECOMMENDATIONS

1. Balsam poplar showed some superior characteristics when compared with trembling aspen. These should be assessed relative to future forest management.

2. Promote the use of these species by the conventional kraft and CTMP processes. Further investigate the potential of using these species by the alkaline sulphite/anthraquinone pulping system.

3. Compile existing information on the effects of rot and stain on the CTMP and kraft processes.

4. Carry out a pulping and bleaching study to assess the effects of rot in the alkaline sulphite/anthraquinone process.

5. For specific projects in a defined forest region, the actual potential of the existing resource should be assessed in each case by appropriate pulping studies.

6. Keep abreast of developments in the solvent pulping field since this study shows some potential in that area.

GENERAL WOOD ASPECTS

The wood for this project was provided by the Alberta Government in late March 1987. In order to obtain representative samples, four major forest areas were selected and five or six sound trees cut from each area. Bolts, 60 m in length were cut from half-way up each tree. The wood was in log form. Identification on the logs is tabulated below together with age as measured at Econotech.

Aspen

Log Markings	Age, yrs
G.P.	26
G.P.	24
G.P.	31
G.P.	29
G.P.	32
G.P.	28
Athabaska	49
Athabaska	43
Athabaska	49
Athabaska	40
Athabaska	46
Athabaska	46
W.C.T.	44
W.C.T.	53
W.C.T.	20
W.C.T.	39
W.C.T.	24
W.C.T.	24
H. Prairie	36
H. Prairie	38
H. Prairie	38
H. Prairie	34
H. Prairie	43
H. Prairie	40

Balsam Poplar

Log Markings	Age, yrs
G.P.	31
G.P.	28
G.P.	29
G.P.	27
G.P.	45
G.P.	32
Athabaska	35
Athabaska	52
Athabaska	63
Athabaska	62
Athabaska	64
W.C.T.	35
W.C.T.	27
W.C.T.	30
W.C.T.	26
W.C.T.	25
W.C.T.	42
H. Prairie	56
H. Prairie	78
H. Prairie	41
H. Prairie	24
H. Prairie	44

The logs were debarked and chipped. Williams classification of the chips gave the following data:

Williams Round Hole Classification

Size	Aspen	Balsam Poplar
+1 1/8"	4.9	6.4
+ 7/8"	27.3	21.9
+ 5/8"	41.7	36.0
+ 3/8"	20.4	26.4
+ 3/16"	4.6	7.8
- 3/16"	1.1	1.5

The data indicate no major difference in chipping characteristics. The aspen gave slightly larger chips than the balsam poplar.

Basic wood characteristics are given in Table 1. Some data on eucalyptus is included for comparison since this species is enjoying major success as a pulp raw material.

The aspen and balsam poplar are relatively low density hardwoods compared with eucalyptus which is medium density. This is only a volumetric disadvantage in terms of wood handling, digester size requirements, etc.

TABLE 1
BASIC WOOD CHARACTERISTICS

	Aspen	Balsam Poplar	A Typical Plantation Eucalyptus
Basic wood density, g/ml	0.348	0.334	0.405
Average fibre length, mm	0.84	0.90	1.11
Cell wall thickness, u	4.0	4.1	1.6
Coarseness, mg/100m	10.1	12.0	-
Wood brightness, T525	62.6	54.1	54

1. BLEACHED KRAFT

Kraft pulping conditions and results are given in Table 2.

Both species pulp easily although the aspen gave higher rejects than the balsam poplar. Compared with softwoods, yield is high (softwoods typically 45-48% total yield) and the low K No. will give reduced environmental impact from bleaching. Chemical requirement is also lower than for softwoods. An example of plantation eucalyptus is also included for comparison. The two Alberta species are seen to give significantly higher yield.

Bleaching conditions and results are given in Table 3. The data show that the aspen and balsam poplar bleach readily to high brightness using the short (low capital) sequence D/CEoD. This is a significant advantage over softwoods.

The bleached pulps were subjected to PFI beater evaluation with detailed results given in Figures 1 to 6. Comparing the two Alberta species, the balsam poplar was significantly the stronger. Table 4 gives a comparison with plantation eucalyptus. This shows generally similar strength for the balsam poplar and eucalyptus but lower strength for the aspen. Bleach kraft eucalyptus pulp is now very well accepted in the market place.

The data indicate that aspen and balsam poplar make a satisfactory raw material for bleached kraft pulp.

TABLE 2
KRAFT PULPING CONDITIONS AND RESULTS

	Aspen	Balsam Poplar	Plantation Eucalyptus
Cook number	B1297	B1298	-
AA, % on o.d. wood	15.0	15.0	12
Sulphidity, %	30.7	30.1	25
L/W	4/1	4/1	3.5/1
Maximum temperature, °C	160	160	170
Time to maximum, minutes	60	60	77
Time at maximum, minutes	70	70	70
Total yield, %	58.2	57.1	54.2
Knots, %	0.8	0.5	0.4
Total rejects, %	4.0	1.7	1.4
K No, 40 ml	9.5	10.3	11.0
Viscosity, 0.5% CED, cp	90.0*	78.2*	80.4
Residual EA, g/L Na_2O	8.07	7.75	1.7
Residual AA, g/L Na_2O	10.8	10.9	3.6

*partially insoluble

TABLE 3
BLEACHING CONDITIONS AND RESULTS

Cook number	B1297-1	B1298-1
Species	Aspen	Balsam Poplar
Pulp type	Kraft	Kraft
K No.	9.5	10.3
D/C: 30% subst, delay 1.5-2 min, 50 min total, 25°C, 3.5% Cs		
ClO_2, as avail Cl_2, %	0.79	0.88
Cl_2, %	1.84	2.05
Residual, g/L avail Cl_2	< 0.01	< 0.01
Eo: 25 psig O_2 (10 min), 60 min total, 71-72°C, 10% Cs		
NaOH, %	1.15	1.30
Final pH	11.4	11.6
K No.	1.2	1.0
Viscosity, 0.5% CED, cp	67.0	54.7
D: 75°C, 9% Cs		
ClO_2, as ClO_2, %	0.8	0.8
NaOH, %	0.36	0.36
Time, hours	4	4
Final pH	4.5	4.7
Residual, g/L avail Cl_2	0.21	0.20
Total yield, %	95.4	94.4
Brightness, Elrepho	91.1	91.7
Viscosity, 0.5% CED, cp	54.2	45.7

TABLE 4
COMPARISON OF BLEACHED KRAFT ASPEN AND
BLEACHED KRAFT PLANTATION EUCALYPTUS PULP STRENGTHS
(PFI DATA @ 500 & 300 CSF)

	Aspen	Balsam Poplar	Plantation Eucalyptus
Properties @ 500 mLs CSF:			
PFI, revs	40	310	50
Burst index, kPa.m²/g	2.80	3.23	3.20
Tear index, mN.m²/g	7.4	8.8	12.4
Tensile index, N.m/g	45	50	54
Density, kg/m³	680	670	645
Porosity, sec/100ml	9	11	5
Opacity, %	74	74	78
Fold, log	1.2	1.4	-
Properties @ 300 mLs CSF:			
PFI, revs	2110	2720	2400
Burst index, kPa.m²/g	6.25	7.40	7.54
Tear index, mN.m²/g	8.4	11.6	11.6
Tensile index, N.m/g	94	102	111
Density, kg/m³	800	890	761
Porosity, sec/100ml	166	100	53
Opacity, %	67	63	72
Fold, log	2.3	3.5	-

BLEACHED KRAFT ASPEN

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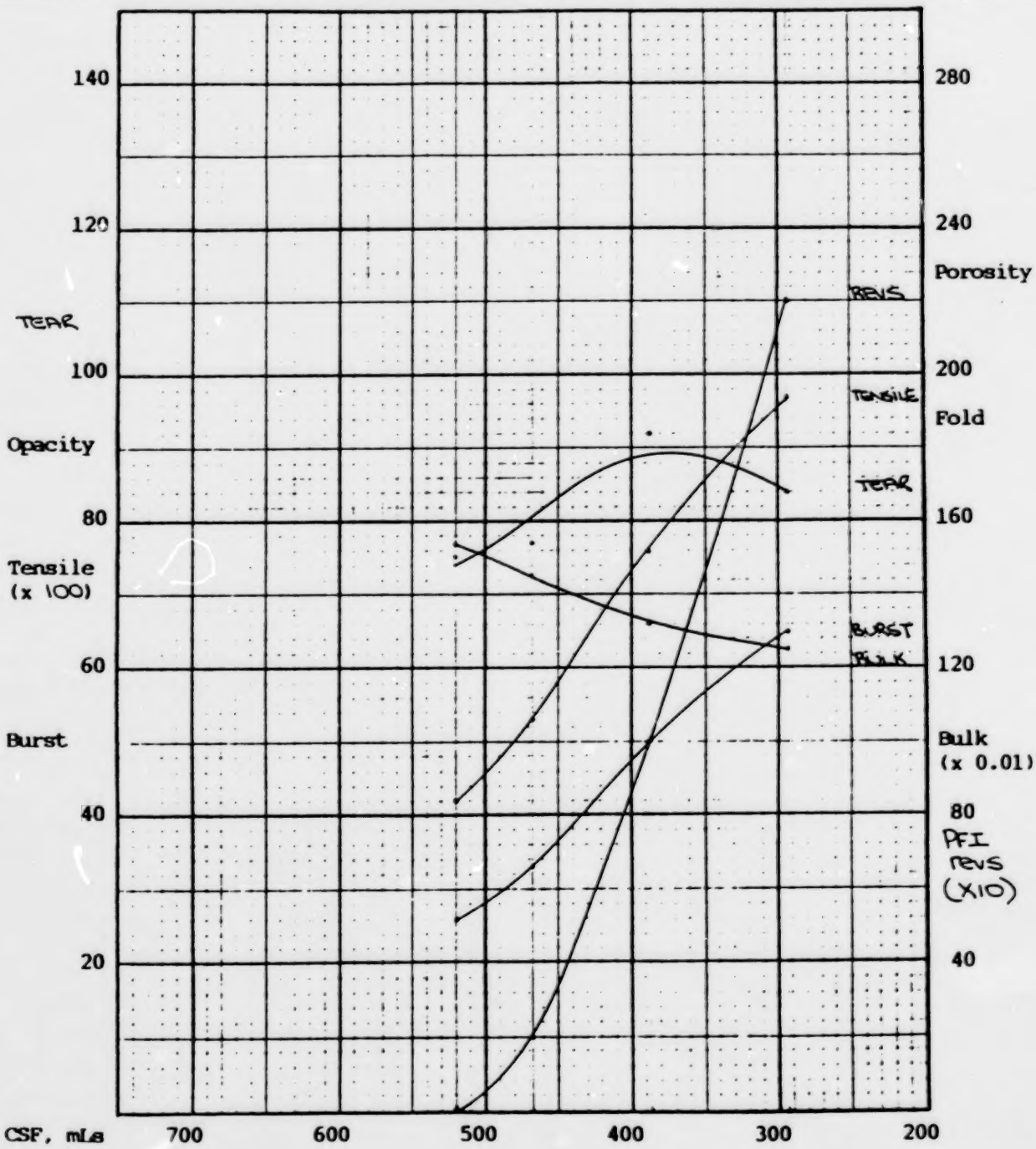
DSS ALBERTA 570024 B1297-1-D ASPEN (KRAFT) 14/08/87 S.W.

CSF mLs	PFI revs	BURST FACTOR	TEAR FACTOR	TENSILE m	BULK cc/g	POROSITY sec/100ml	OPACITY %	FOLD COUNT	VISCOSITY 0.5% CED
520	0	26	74	4200	1.50	8	75	13	
500	40	28	76	4600	1.51	9	74	21	
400	860	48	84	7400	1.34	36	71	94	
300	2110	64	85	9600	1.26	166	67	178	

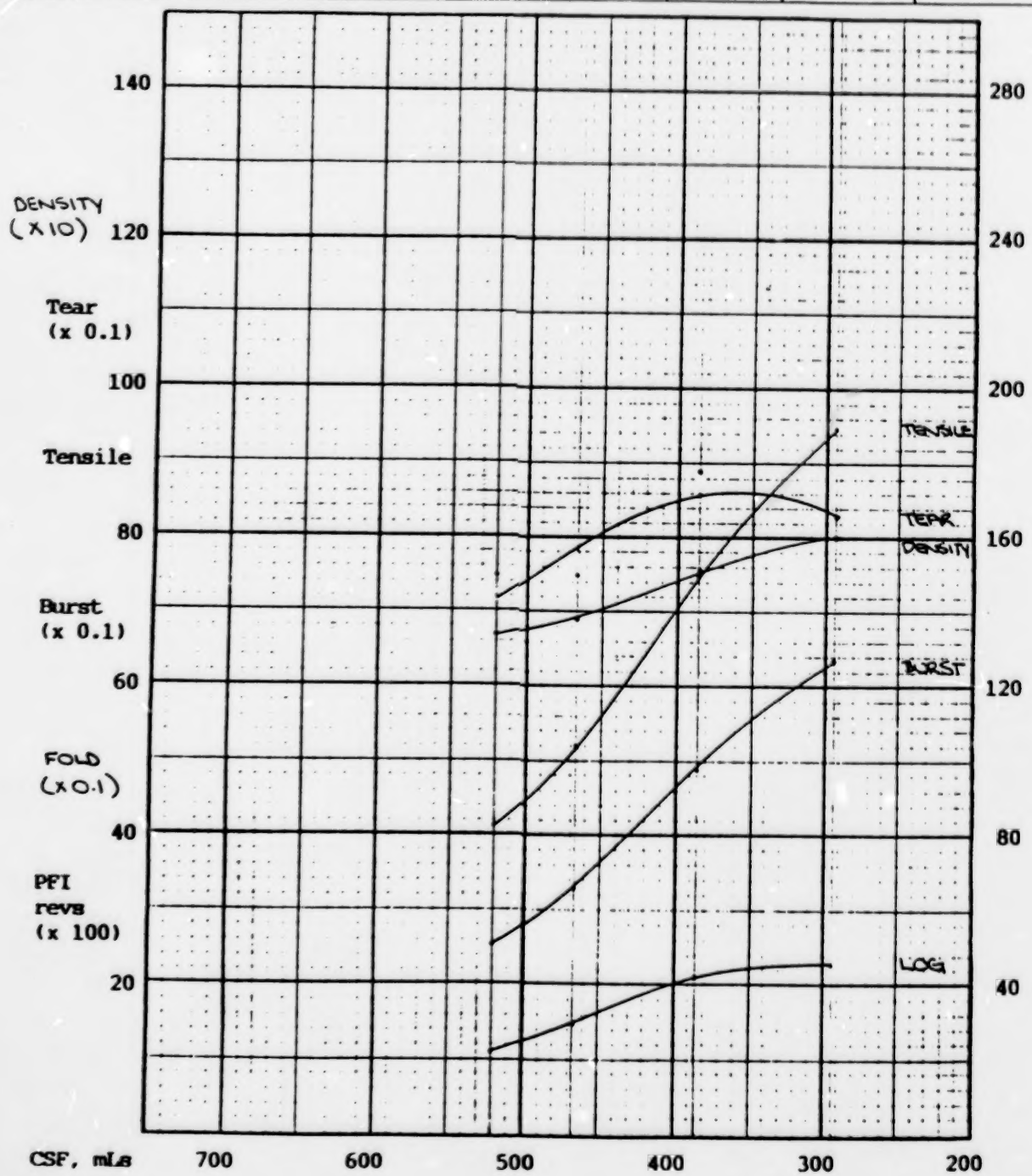


ECONOTECH

BLEACHED KRAFT (7-31 PEN

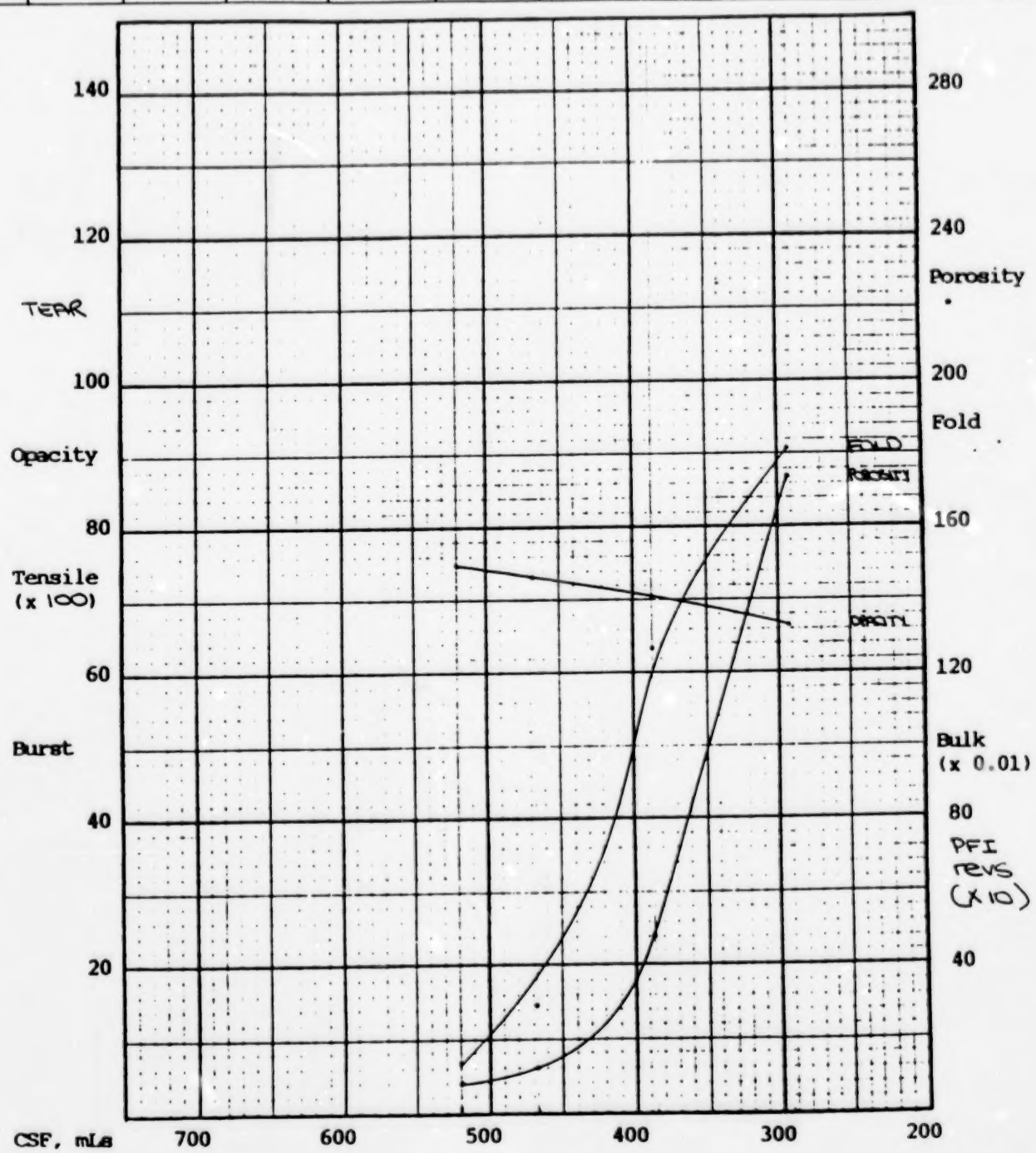
DSS ALBERTA 5700354 B13897-1-D (KRAFT) 14/08/87 SW

CSF mLs	PFI revs	BURST INDEX kPa.m2/g	TEAR INDEX mN.m2/g	TENSILE N.m/g	DENSITY Kg/m3	FOLD LOG	VISCOSITY 0.5% CED, cp
520		2.56	7.2	41	667	1.1	
500		2.80	7.4	45	680	1.2	
400		4.63	8.5	70	740	2.0	
300		6.25	8.4	94	800	2.3	



DSS ALBERTA 570239 B1397-1-D ASPEN (KRAFT) 14/08/87 SLO

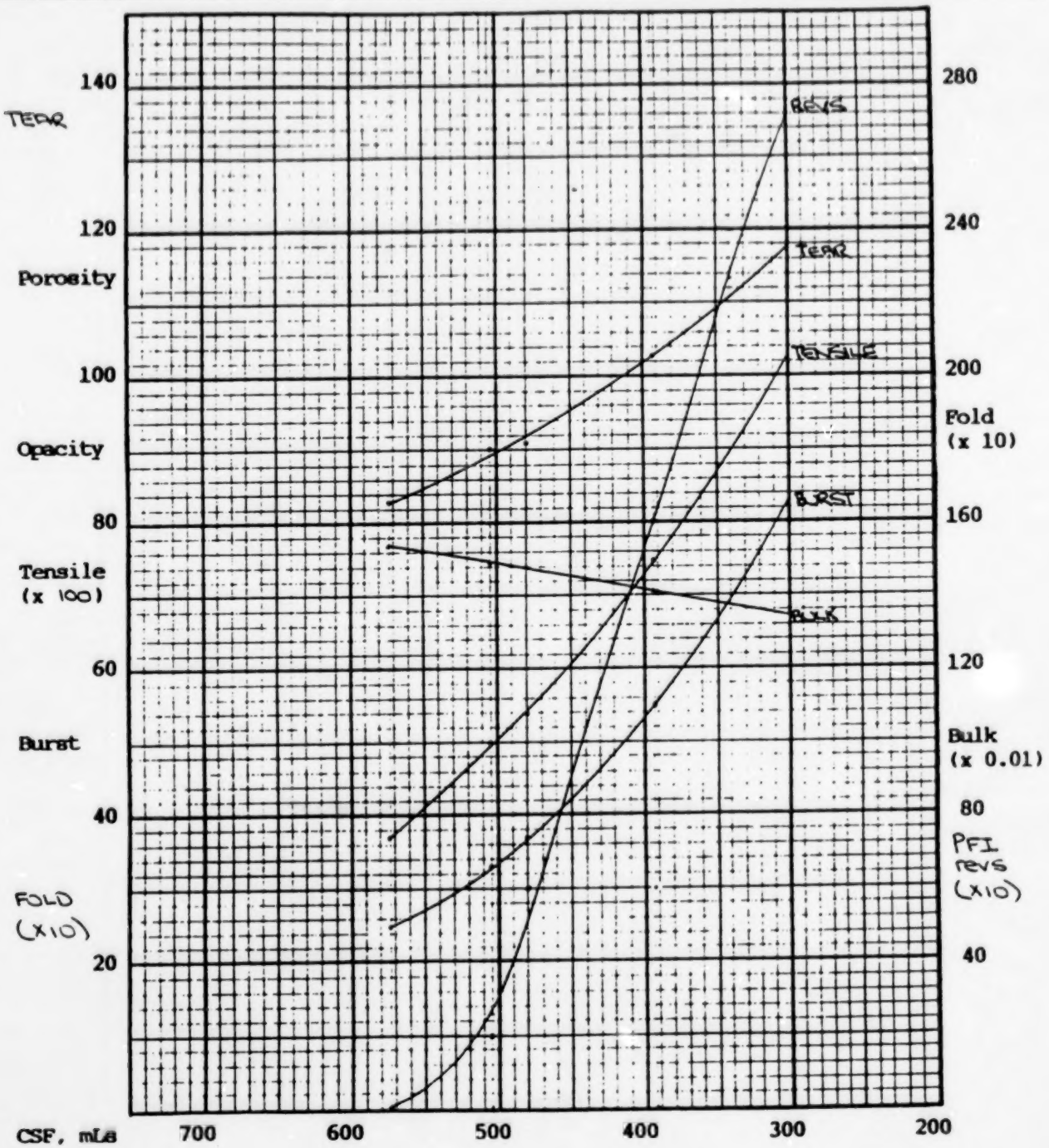
CSF mLs	PFI revs	BURST FACTOR	TEAR FACTOR	TENSILE m	BULK cc/g	POROSITY sec/100ml	OPACITY %	FOLD COUNT	VISCOSITY 0.5% CED
520						8	75	13	
500						9	74	21	
400						36	71	99	
300						166	67	178	



BEATEN KRAFT BALSAM POPLAR

DSS ALBERTA 570034 B29B-1-D BALSAM/POPLAR (KRAFT) 14/08/87 SLO

CSF mLs	PFI revs	BURST FACTOR	TEAR FACTOR	TENSILE m	BULK cc/g	POROSITY sec/100ml	OPACITY %	FOLD COUNT	VISCOSITY 0.5% CED
574	0	25	83	3700	1.54	7	77	11	
500	310	33	90	5000	1.49	11	74	20	
400	1520	54	102	7300	1.41	31	69	180	
300	2720	83	117	10300	1.37	100	63	1230	

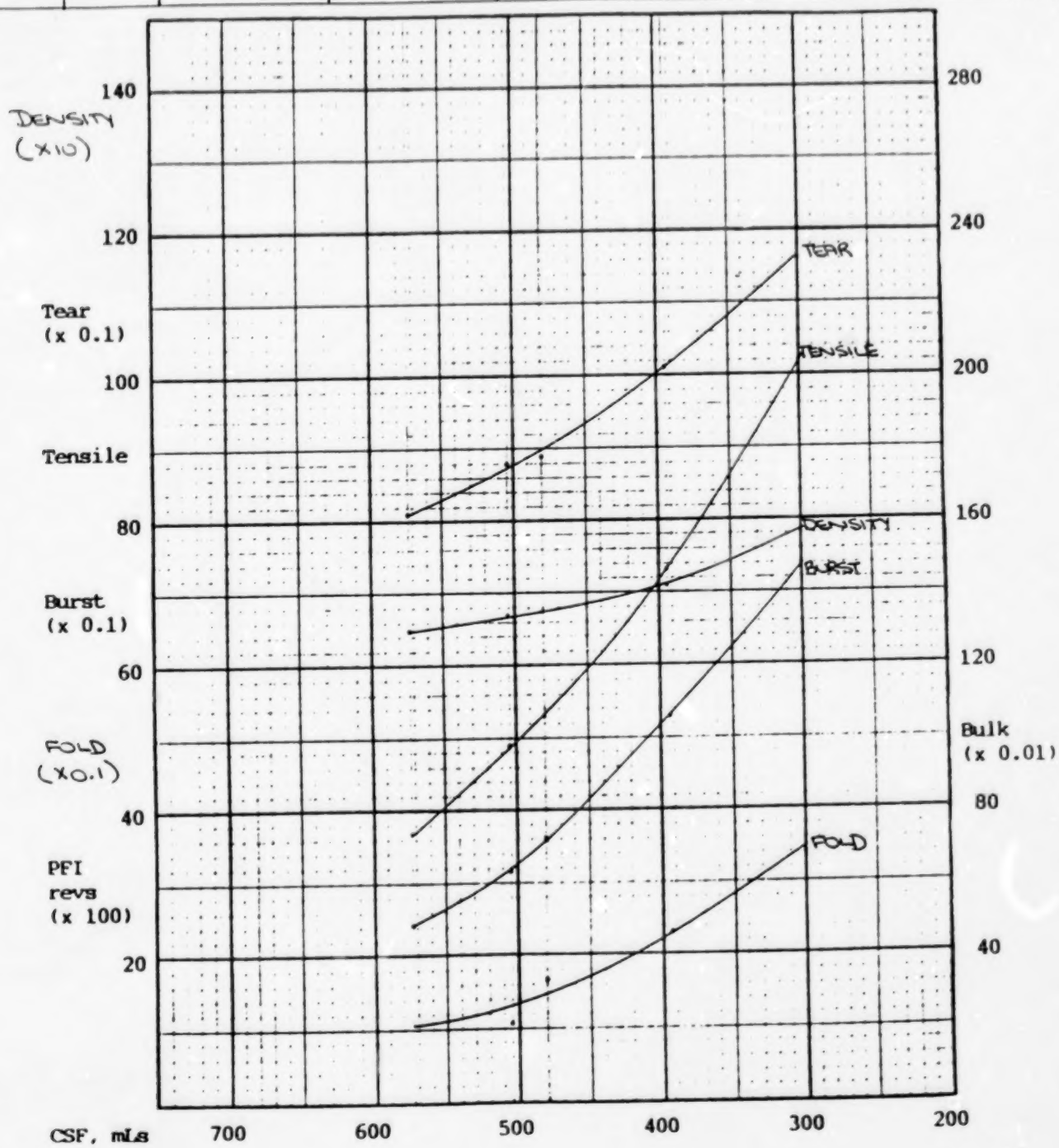


ECONOTECH

BLEACHED KRAFT BALSAM POPLAR

DSS ALBERTA 570234 3B3B3 1-D BALSAM/POPLAR (KRAFT) 14/08/87SM

CSF mLs	PFI revs	BURST INDEX kPa.m2/g	TEAR INDEX mN.m2/g	TENSILE N. m/g	DENSITY Kg/m³	FOLD (log)	VISCOSITY 0.5% CED, cp
574		2.41	8.1	37	679	1.0	
500		3.23	9.8	50	690	1.4	
400		5.20	10.0	72	710	2.2	
300		7.40	11.6	102	890	3.5	



ECONOTECH

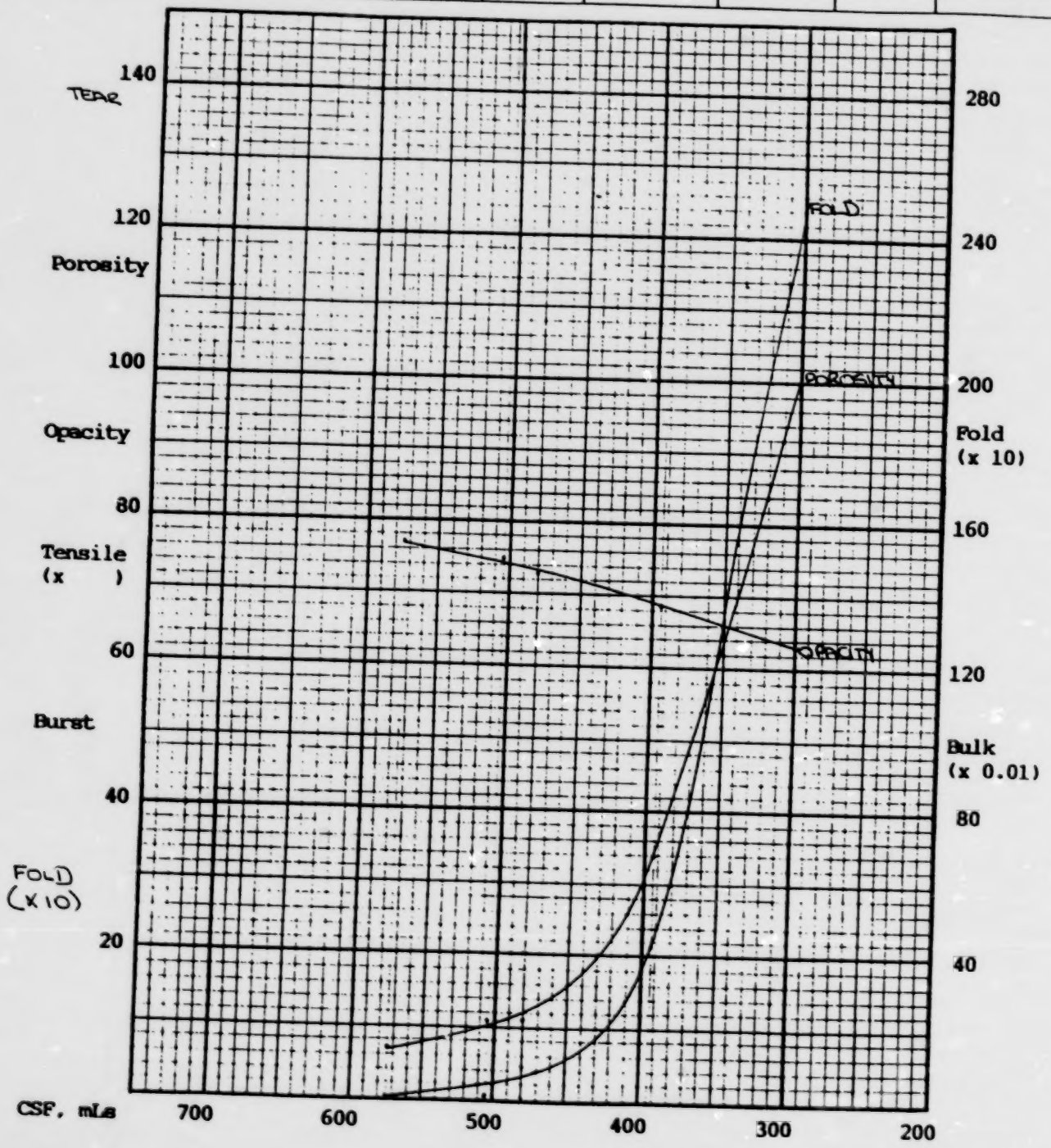
BLEACHED KRAFT BALSAM POPLAR

14/03/87 SW

DSS ALBERTA 570034

B1398-1-D BALSAM/POPLAR (KRAFT)

CSF mLs	PFI revs	BURST FACTOR	TEAR FACTOR	TENSILE km	BULK cc/g	POROSITY sec/100ml	OPACITY %	FOLD COUNT	VISCOSITY 0.5% CED
						7	77	11	
						11	74	20	
						31	69	180	
						100	63	1230	



2. BLEACHED ALKALINE SULPHITE/ANTHRAQUINONE

Pulping conditions and results are given in Table 5. The ASAQ process offers the advantage of giving a low odour, high yield system producing a pulp of good strength characteristics. Table 5 confirms the superior unbleached yield over the kraft process. Table 6 shows that the pulp bleached easily to very high brightness. Overall yield was similar to kraft. Strength characteristics are detailed in Figures 7-12. Many kraft pulps are now used at relatively high freeness levels. In this respect, the data show that the Alberta species actually give an advantage compared with kraft, when pulped by the ASAQ process. A comparison of kraft and ASAQ strengths is given in Table 7.

Since the ASAQ process does show promise with these species, it is felt that further assessment of the process should be carried out with this including the effects of rot and stain.

TABLE 5
ALKALINE SULPHITE/ANTHRAQUINONE (ASAQ)
PULPING CONDITIONS AND RESULTS

Cook number	L76-1	L76-3
Furnish	Aspen	Balsam Poplar
Chemical charge:		
Total Na_2O, %	19.29	19.29
Na_2SO_3, % of total as Na_2O	74.65	74.65
Na_2CO_3, % of total as Na_2O	15.97	15.97
NaOH, % of total as Na_2O	9.38	9.38
THAQ, % on o.d. wood	0.1	0.1
L/W	5/1	5/1
Maximum temperature, °C	165	165
Time at maximum, minutes	240	240
Total yield, %	60.9	57.5
K No, 40 ml	12.5	12.2
Kappa number	18.2	18.2
Total rejects, %	0.7	2.6
Initial pH of liquor	13.19	13.26
pH of spent liquor	9.06	9.28
Pulp viscosity, 0.5% CED, cp	105.7	123.3

Other conditions:

Presteaming for 3 minutes at atmospheric pressure
25 minutes from 90°C to 130°C
45 minutes at 130°C
30 minutes from 130°C to 168°C
Cooked chips hot refined at 0.050" and then at 0.020"
Pulps screened through 12 cut flat screen.

TABLE 6
BLEACHING CONDITIONS AND RESULTS FOR ASAQ PULPS

Cook number	L76-1	L76-3
Species	Aspen	Balsam Poplar
Pulp type	ASAQ	ASAQ
K No.	12.5	12.2
Kappa number	18.2	18.2
D/C: 30% subst, delay 1.5-2 min, 50 min total, 25°C, 3.5% Cs		
ClO_2, as avail Cl_2, %	1.20	1.20
Cl_2, %	2.80	2.80
Final pH	-	2.0
Residual, g/L avail Cl_2	0.01	0.01
Eo: 25 psig O_2 (10 min), 60 min total, 71-72°C, 10% Cs		
NaOH, %	1.75	1.75
Final pH	12.1	12.0
K No.	0.5	0.4
Viscosity, 0.5% CED, cp	85.8	102
D: 75°C, 9% Cs		
ClO_2, as ClO_2, %	0.3	0.3
NaOH, %	0.06	0.06
Time, hours	3	3
Final pH	5.0	5.0
Residual, g/L avail Cl_2	0.13	0.12
Total yield, %	91.6	91.6
Brightness, Elrepho	92.2	91.7
Viscosity, 0.5% CED, cp	74.1	89.2

TABLE 7
COMPARISON OF KRAFT AND ASAQ PULP STRENGTHS
FOR ASPEN AND BALSAM POPLAR
(PFI DATA @ 500 & 300 CSF)

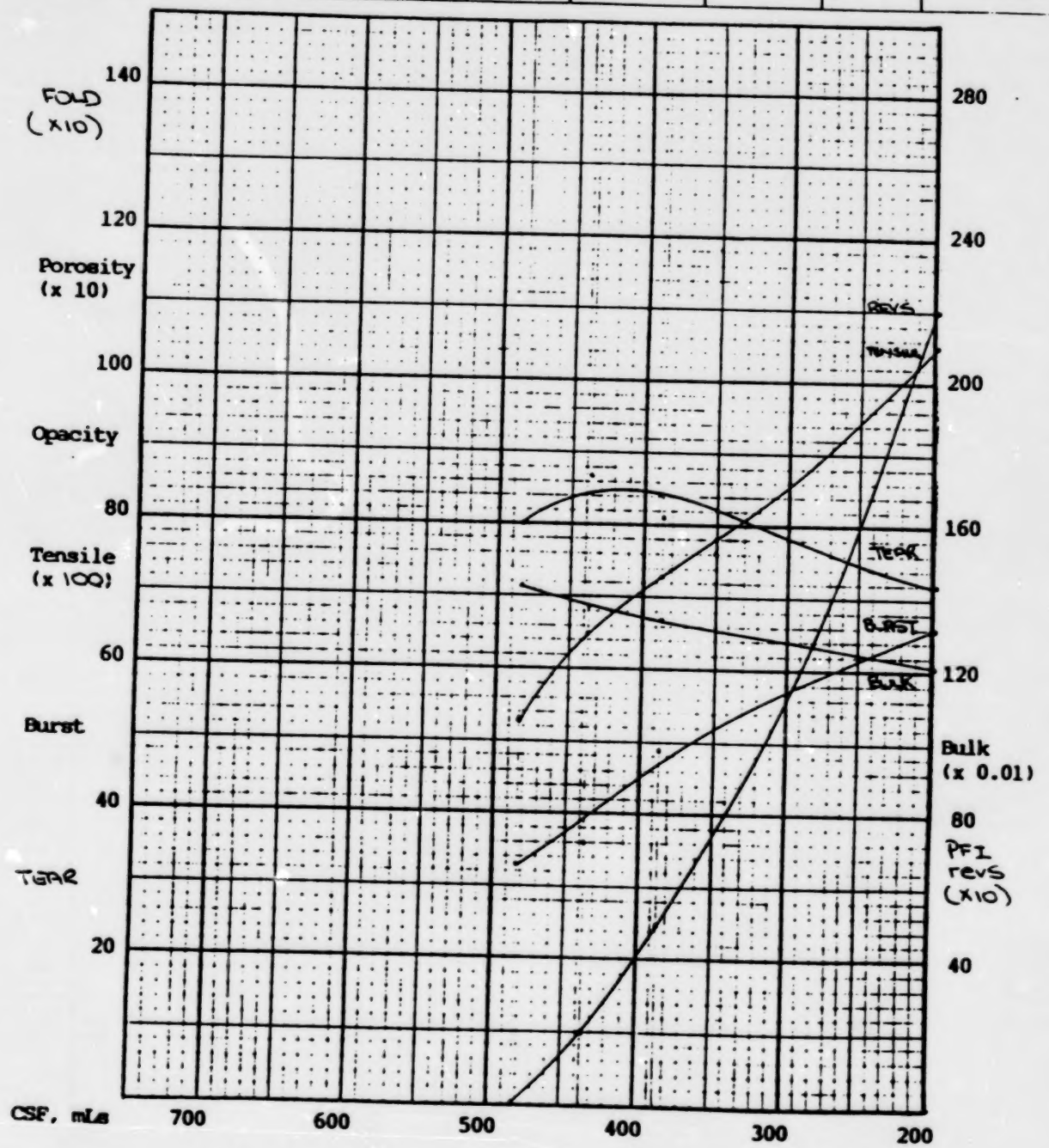
	Kraft		ASAQ	
	Aspen	Balsam Poplar	Aspen	Balsam Poplar
Properties @ 500 mLs CSF:				
PFI, revs	40	310	0	140
Burst index, kPa.m²/g	2.80	3.23	3.26	3.20
Tear index, mN.m²/g	7.4	8.8	7.8	9.5
Tensile index, N.m/g	45	50	52	52
Density, kg/m³	680	670	699	690
Porosity, sec/100ml	9	11	13	14
Opacity, %	74	74	72	74
Fold, log	1.2	1.4	1.4	1.3
Properties @ 300 mLs CSF:				
PFI, revs	2100	2720	1120	2400
Burst index, kPa.m²/g	6.25	7.40	5.42	7.32
Tear index, mN.m²/g	8.4	11.5	7.5	8.3
Tensile index, N.m/g	94	102	86	90
Density, kg/m³	800	890	780	810
Porosity, sec/100ml	166	100	130	187
Opacity, %	67	63	66	66
Fold, log	2.3	3.5	2.6	3.9

BLEACHED ASAQ ASPEN

ECONOTECH

Dias ALBERTA 570036 L76-1-D ASPEN (SULFITE AQ) 14/08/87 SLO

CSF mLs	PFI revs	BURST FACTOR	TEAR FACTOR	TENSILE m	BULK cc/g	POROSITY sec/100ml	OPACITY %	FOLD COUNT	VISCOSITY 0.5% CED
482	0	33	80	5300	1.43	13	72	35	
400	400	45	85	7100	1.34	40	69	100	
300	1120	57	78	8600	1.28	130	66	310	

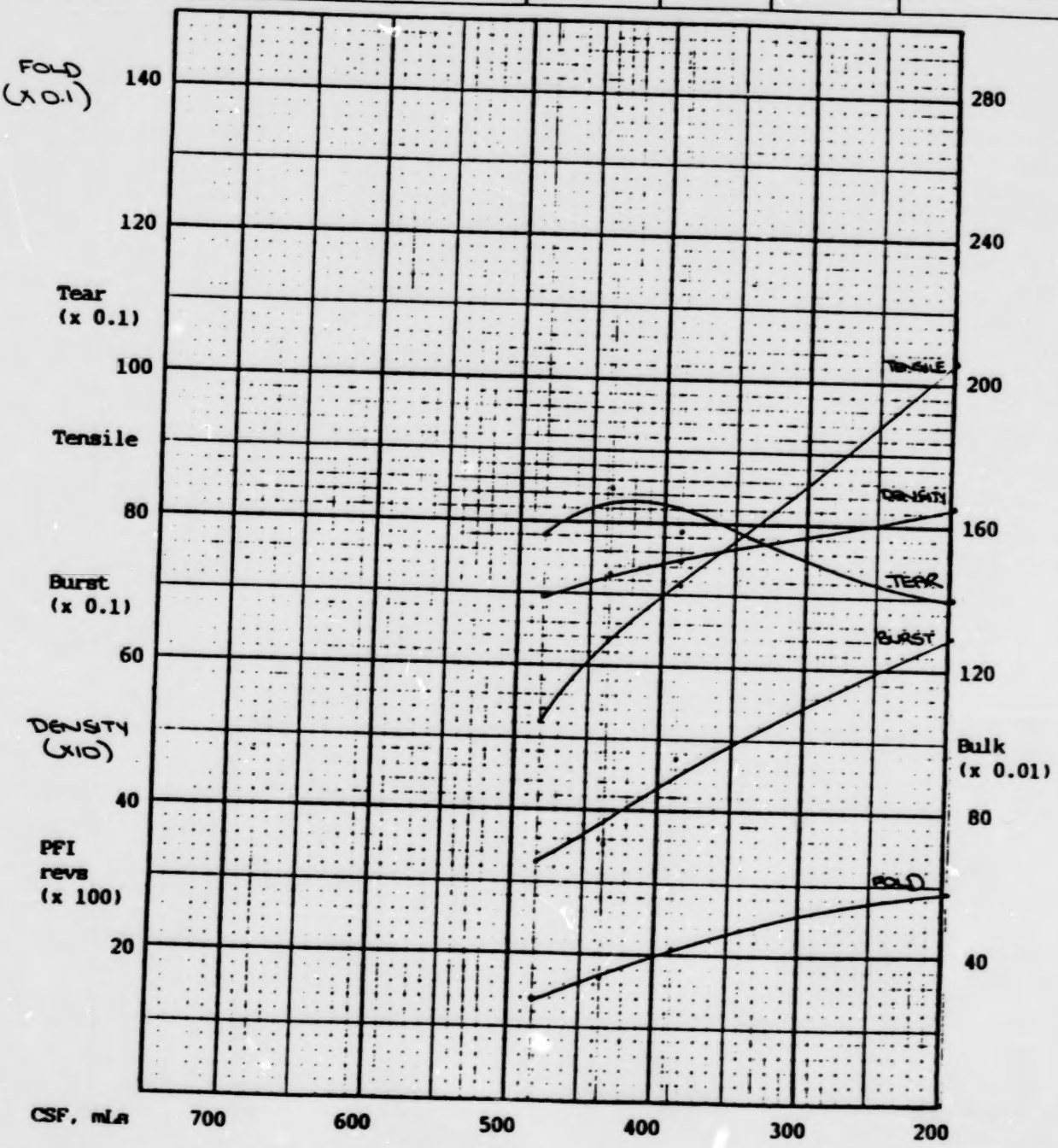


ECONOTECH

BLEACHED AYAG ASPEN

Dds ALBERTA 570024 L7161-D ASPEN (SULFITE AM) 14/08/91 ELD

CSF mLs	PFI revs	BURST INDEX kPa.m2/g	TEAR INDEX mN.m2/g	TENSILE N.m/g	DENSITY Kg/m3	FOLD (LOG)	VISCOSITY 0.5% CED, cp
422		3.26	7.8	52	669	1.4	
400		4.37	8.3	70	740	2.0	
300		5.42	7.5	86	780	2.6	

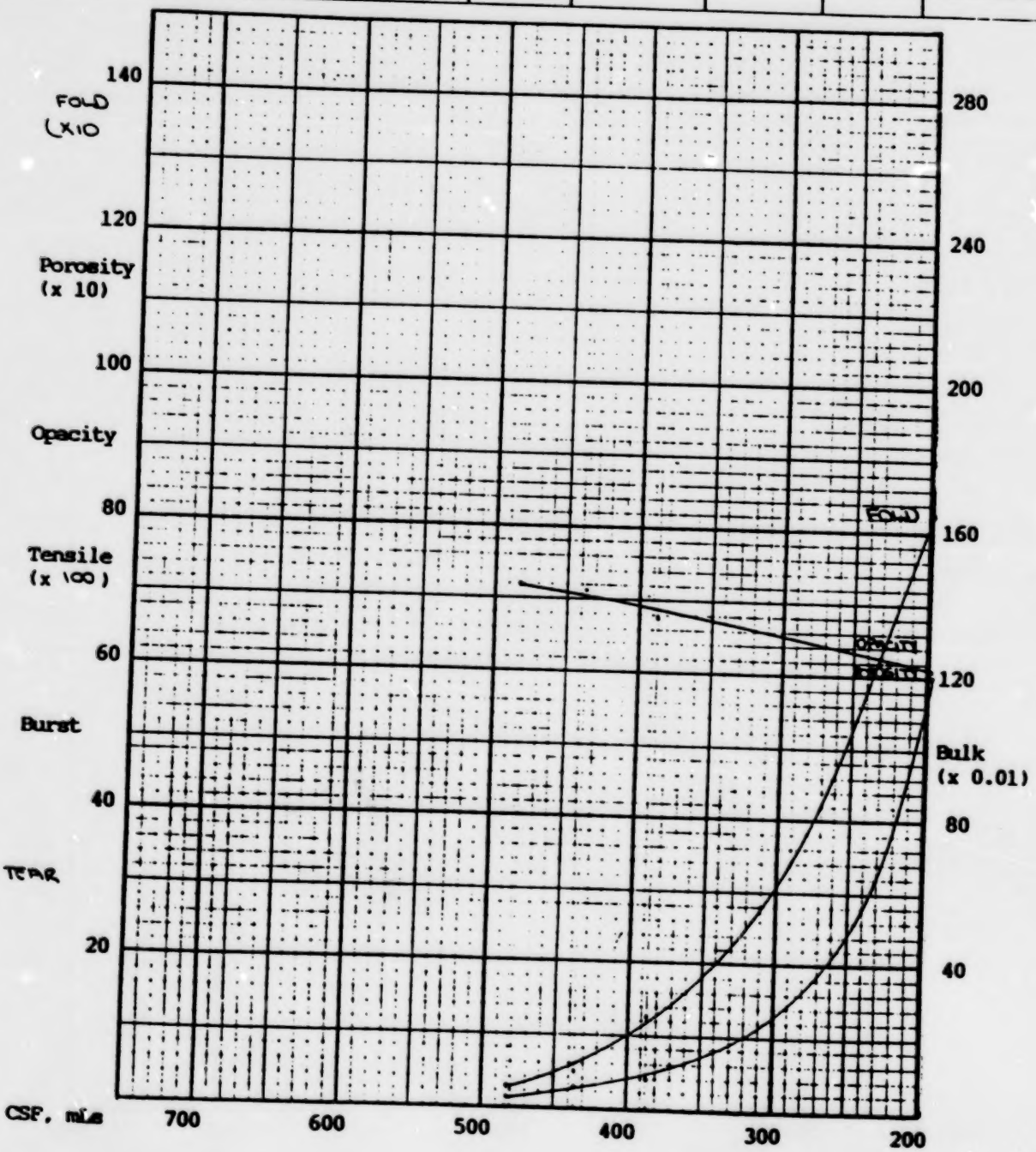


ECONOTECH

BLEACHED ASAQ ASPEN

DSS ALBERTA 570035 L76-1-D ASPEN (SULFITE AQ) 14/03/87 SW

CSF mLs	PFI revs	BURST FACTOR	TEAR FACTOR	TENSILE km	BULK cc/g	POROSITY sec/100ml	OPACITY %	FOLD COUNT	VISCOSITY 0.5% CED
482									
400						13	72	25	
300						40	69	100	
						130	66	310	

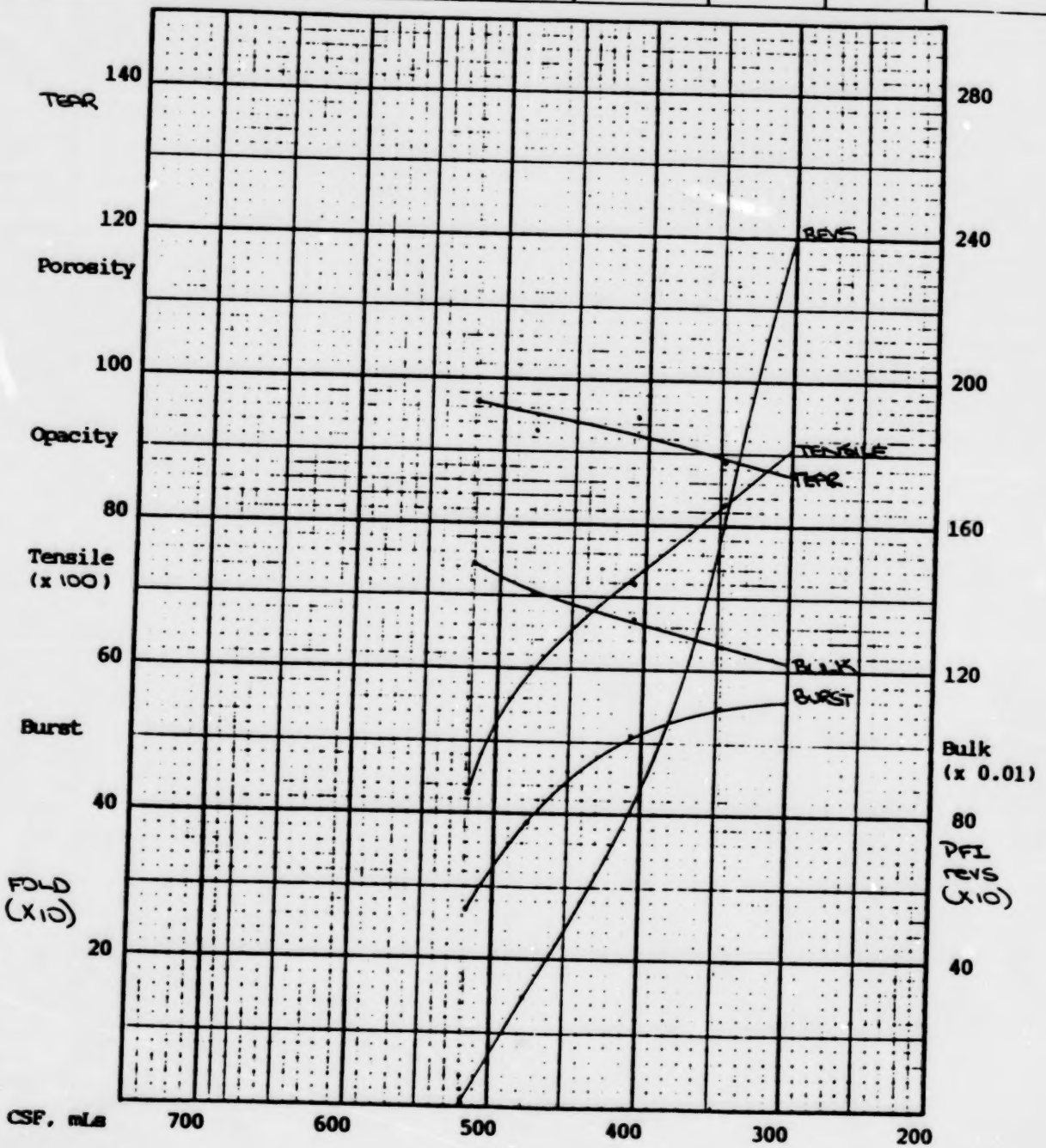


ECONOTECH

BLEACHED ASAQ B. POPLAR

D&S ALBERTA 5/10/84 L76-3-D BALSAM/POPLAR (SULFITE PP) 4 lobed SW

CSF mLs	PFI revs	BURST FACTOR	TEAR FACTOR	TENSILE m	BULK cc/g	POROSITY sec/100ml	OPACITY %	FOLD COUNT	VISCOSITY 0.5% CED
516	0	27	97	4300	1.49	9	75	14	
500	140	33	96	5300	1.45	14	74	20	
400	870	51	92	7400	1.32	47	69	130	
300	2400	56	87	9100	1.22	197	66	1800	

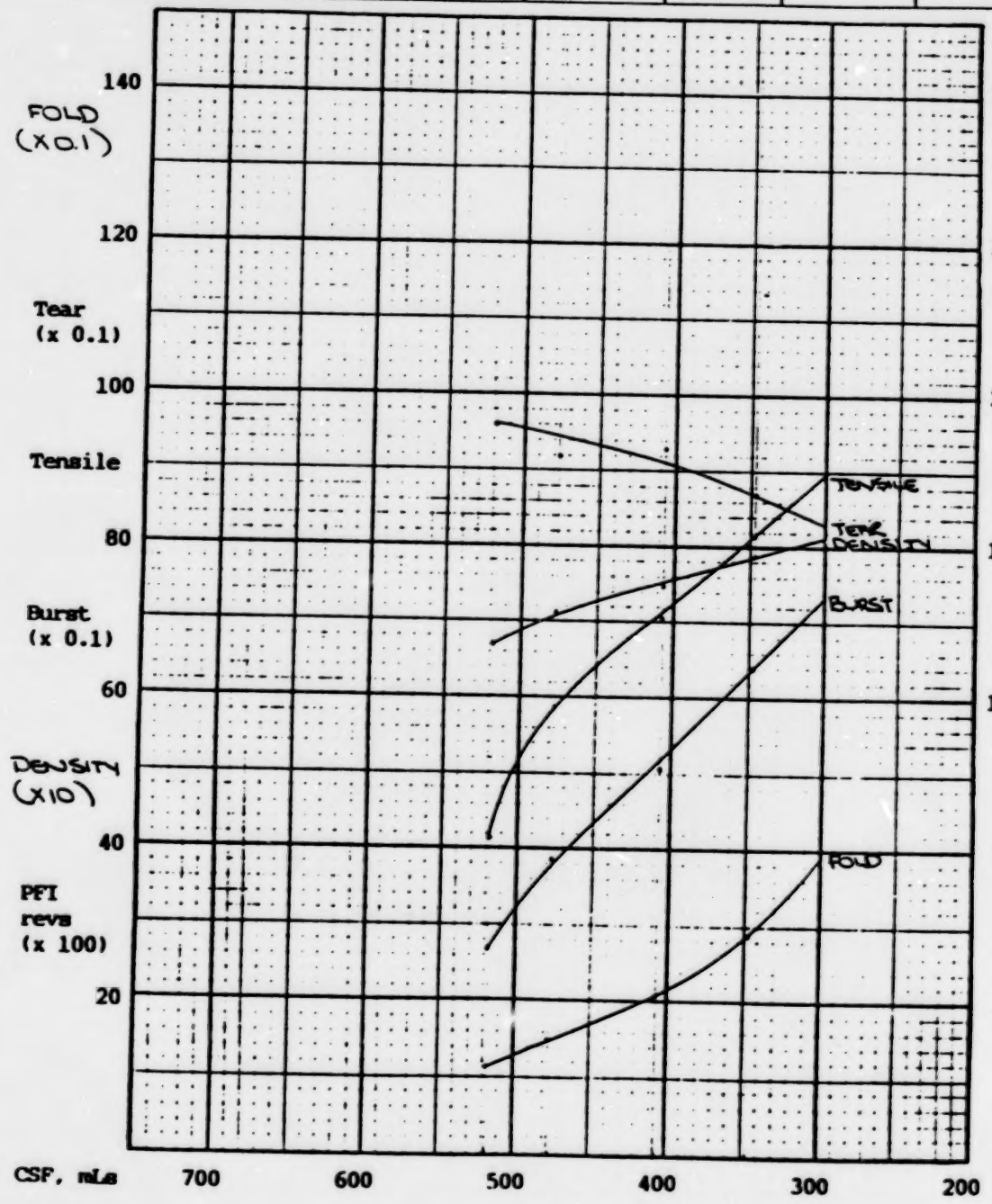


ECONOTECH

BLEACHED ASA BALSAM POPLAR

DSS ALBERTA 570034 L716-3-D BALSAM/POPLAR (SULFITE AQ) 14/08/87 SW

CSF mLs	PFI revs	BURST INDEX kPa.m2/g	TEAR INDEX mN.m2/g	TENSILE N.m/g	DENSITY kg/m3	FOLD (10^6)	VISCOSITY 0.5% CED, cp
519		2.61	9.6	42	671	1.2	
500		3.20	9.5	52	690	1.3	
400		5.36	9.1	72	760	22	
300		7.32	8.3	90	810	39	

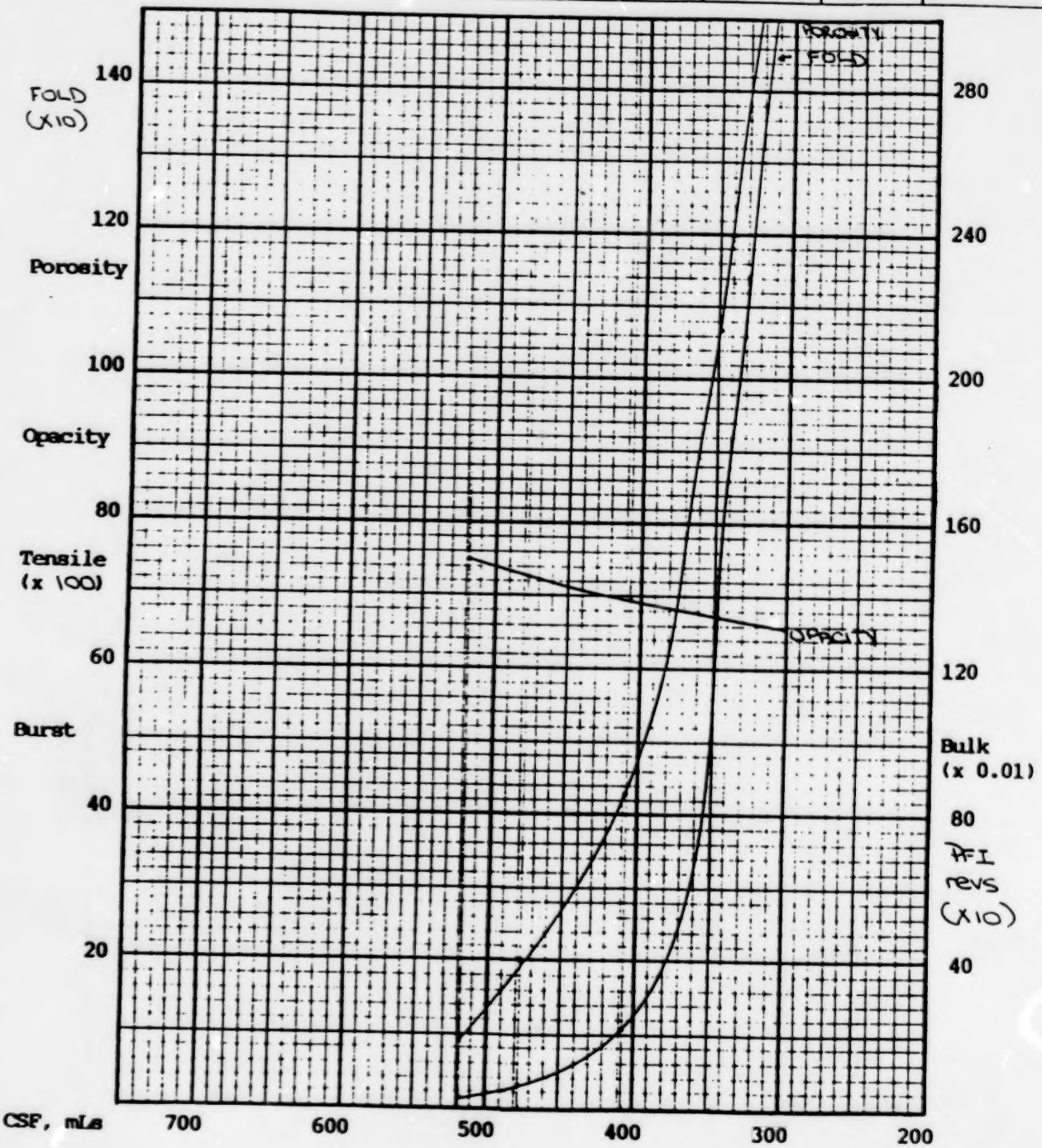


ECONOTECH

BLEACHED ASAC B [illegible]

255 ALBERTA 570039 L76-3-D BALSAM/POPLAR (SULFITE AW) 14/08/87 SW

CSF mLs	PFI revs	BURST FACTOR	TEAR FACTOR	TENSILE km	BULK cc/g	POROSITY sec/100ml	OPACITY %	FOLD COUNT	VISCOSITY 0.5% CED
5H						9	75	14	
500						14	74	20	
400						47	69	130	
300						187	66	1800	



3. BLEACHED SOLVENT (METHANOL) PULP

The use of a methanol based process for aspen and balsam poplar offers potential advantages for Alberta relative to the chemical used and the possible use of lignin and carbohydrate by-products. Solvent recovery and by-product aspects have not yet been proven at mill scale but one tonnage pilot plant has been completed and another is under construction.

Pulping conditions and results are given in Table 8. The two species gave very high unbleached yield as expected for the high kappas. Some of this high yield is lost in bleaching to give similar overall yield to that of kraft.

Short sequence bleaching (Table 9) was not as effective as with kraft and ASAQ, but still gave 90 brightness pulp.

Strength characteristics are detailed in Figures 13-18 and like ASAQ, show superior burst and tensile compared to kraft at the higher freeness levels although tear is slightly lower. Table 10 gives a comparison of kraft and solvent pulp strength.

Owing to the unique aspects of this process - low odour, potential low pollution, chemical requirements possibly

favorable to Alberta, economic mill size smaller than for kraft and by-product recovery - it is recommended that its applicability to Alberta hardwoods be further investigated.

TABLE 8
SOLVENT PULPING (METHANOL) CONDITIONS AND RESULTS

Cook number	DSS #1	DSS #2
Furnish	Aspen	Balsam Poplar
Weight of chips, o.d. g	400	400
Cooking liquor:		
Methanol, l	6.40	6.40
Water, l	1.21	1.08
$MgSO_4$, g · 7 H_2O	98.0	98.0
L/W	20/1	20/1
Maximum temperature, °C	190	190
Total cooking time, hrs:min	3:00	3:00
Initial pH	4.90	5.0
End pH	4.64	4.84
Total yield, %	63.8	66.3
Kappa number	39.7	54.0
Viscosity, 0.5% CED, cp	42.6*	29.0*

*partially insoluble

NOTE:
Chips were defibred using Lightnin mixer
Sprout-Waldron refined @ 0.015"
Screened through 0.010" cut flat screen

TABLE 9
BLEACHING CONDITIONS AND RESULTS

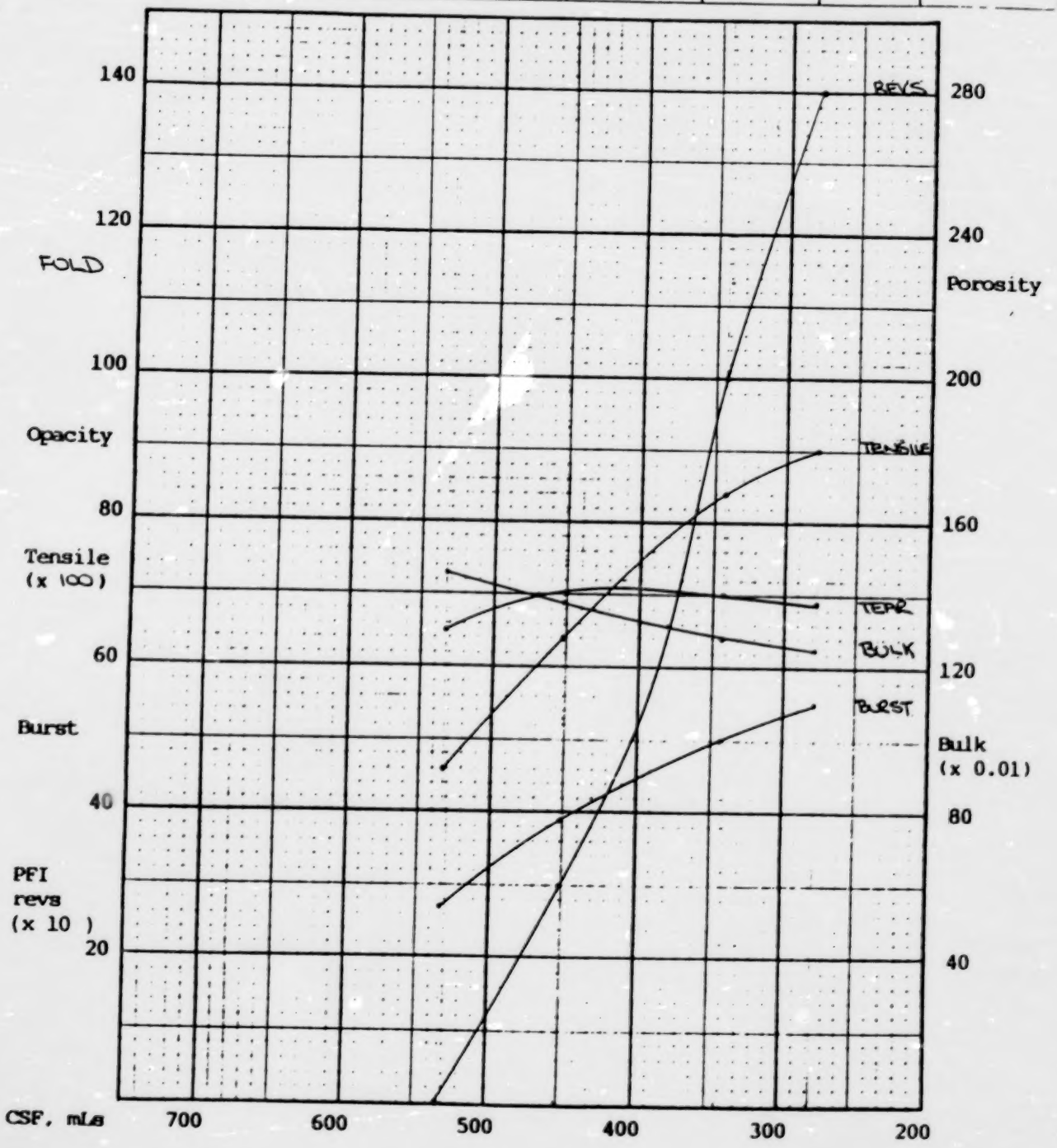
Cook number	AP-1	AP-2
Species	Aspen	Balsam Poplar
Pulp type	Alcohol	Alcohol
Kappa number	39.7	54.0
D/C: 30% subst, delay 1.5-2 min, 50 min total, 25°C, 3.5% Cs		
ClO_2, as avail Cl_2, %	2.38	3.24
Cl_2, %	5.56	7.56
Final pH	1.3	1.3
Residual, g/L avail Cl_2	0.01	0.01
Eo: 25 psig O_2 (10 min), 60 min total, 71-72°C, 10% Cs		
NaOH, %	3.4	4.7
Final pH	10.0	10.4
K No.	0.7	1.0
Viscosity, 0.5% CED, cp	63.9	69.7
D: 75°C, 9% Cs		
ClO_2, as ClO_2, %	0.6	0.8
NaOH, %	0.18	0.32
Time, hours	4	4
Final pH	3.6	3.9
Residual, g/L avail Cl_2	0.17	0.17
Total yield, %	87.4	83.3
Brightness, Elrepho	89.8	89.7
Viscosity, 0.5% CED, cp	63.4	62.3

TABLE 10
COMPARISON OF KRAFT AND SOLVENT PULP STRENGTHS
FOR ASPEN AND BALSAM POPLAR
(PFI DATA @ 500 & 300 CSF)

	Kraft		Solvent	
	Aspen	Balsam Poplar	Aspen	Balsam Poplar
Properties @ 500 mLs CSF:				
PFI, revs	40	310	120	70
Burst index, kPa.m²/g	2.80	3.23	3.20	3.40
Tear index, mN.m²/g	7.4	8.8	6.6	7.7
Tensile index, N.m/g	45	50	53	52
Density, kg/m³	680	670	700	700
Porosity, sec/100ml	9	11	16	18
Opacity, %	74	74	73	72
Fold, log	1.2	1.4	1.4	1.3
Properties @ 300 mLs CSF:				
PFI, revs	2110	2720	1250	1530
Burst index, kPa.m²/g	6.25	7.40	5.31	6.07
Tear index, mN.m²/g	8.4	11.6	6.9	7.5
Tensile index, N.m/g	94	102	87	91
Density, kg/m³	800	890	800	800
Porosity, sec/100ml	166	100	130	164
Opacity, %	67	63	67	64
Fold, log	2.3	3.5	1.7	2.5

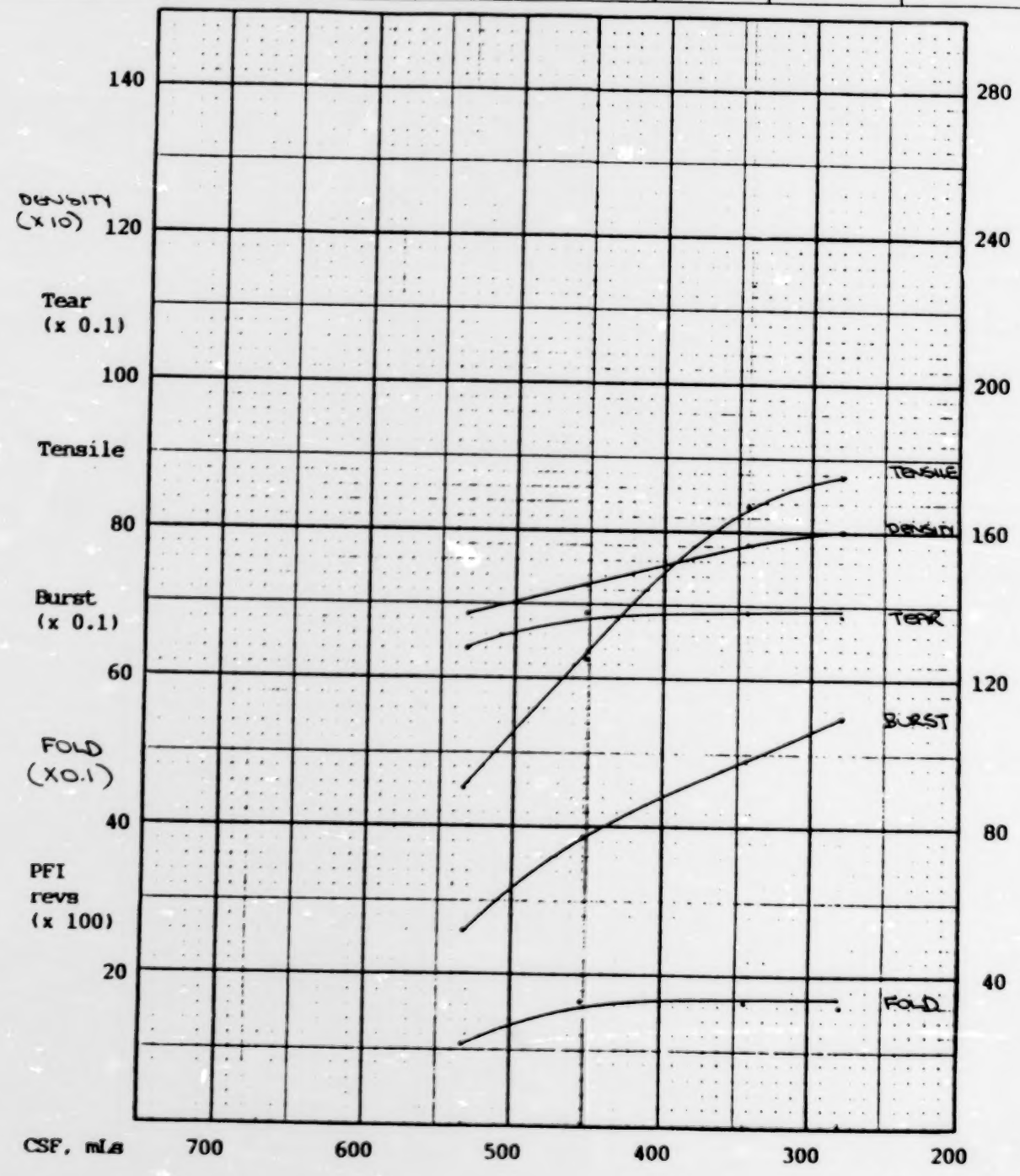
DOS ALBERTA 570034 API-D(METHANOL-COOK) ASPEN 12/08/87 SLO

CSF mLs	PFI revs	BURST FACTOR	TEAR FACTOR	TENSILE m	BULK cc/g	POROSITY sec/100ml	OPACITY %	FOLD COUNT	VISCOSITY 0.5% CED
532	0	27	65	4600	1.46	11	74	11	
500	120	32	68	5400	1.42	16	73	23	
400	520	45	71	7500	1.32	50	70	41	
300	1250	54	69	8300	1.26	130	67	46	



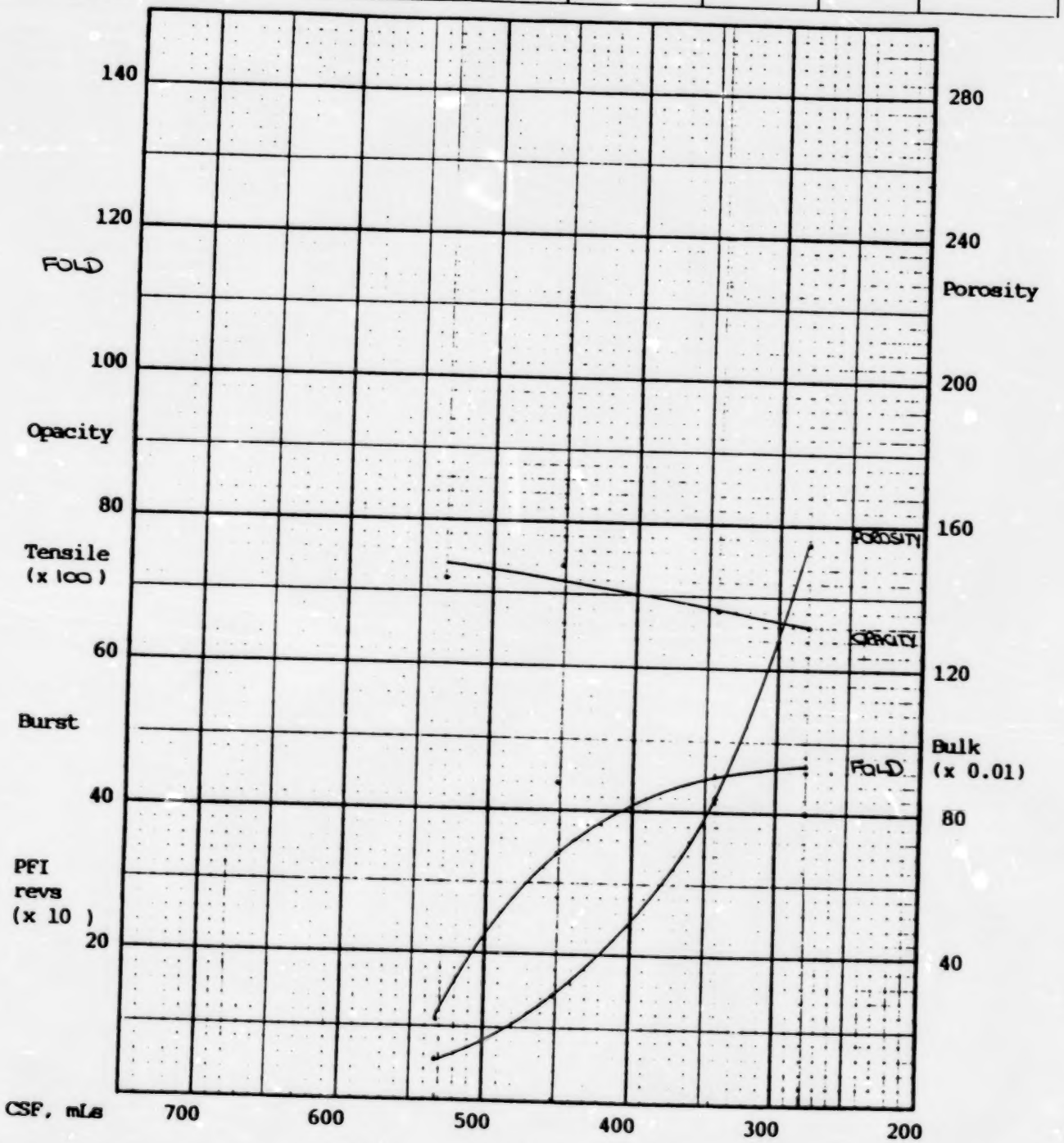
D55 ALBERTA 570039 API-D (METHANOL COOK) ASPEN 13/08/87 SLJ

CSF mls	PFI revs	BURST INDEX kPa.m2/g	TEAR INDEX mN.m2/g	TENSILE N.m/g	DENSITY kg/m3	FOLD (log)	VISCOSITY 0.5% CED, cp
532		2.60	6.4	45	695	1.04	
500		3.20	6.6	53	700	1.36	
400		4.40	6.8	74	760	1.65	
300		5.31	69	87	800	1.70	



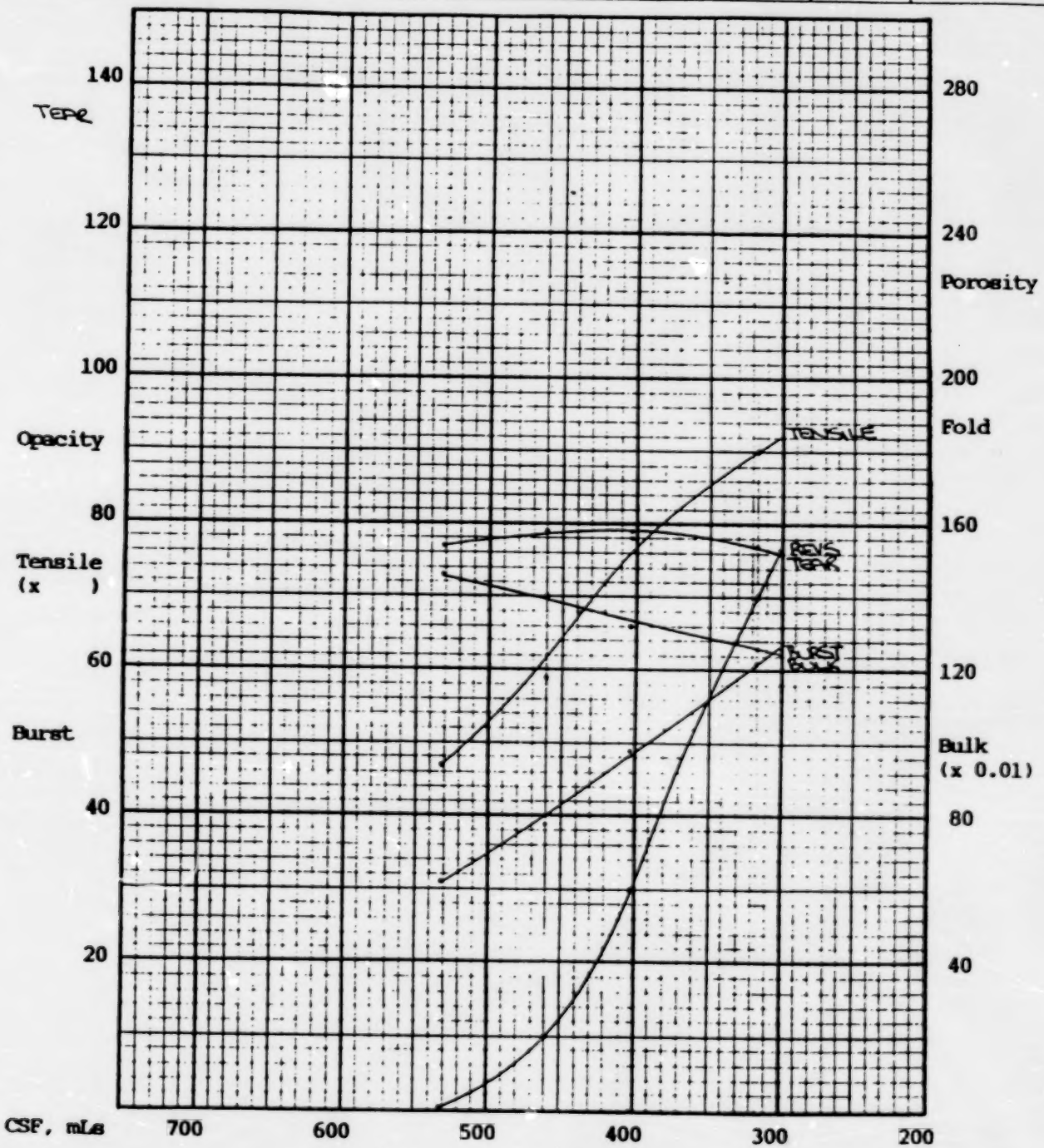
DSS ALBERTA 5710354 AA1-D(METHANOL COOK) ASPEN 12/08/87 S.J.

CSF mLs	PFI revs	BURST FACTOR	TEAR FACTOR	TENSILE m	BULK cc/g	POROSITY sec/100ml	OPACITY %	FOLD COUNT	VISCOSITY 0.5% CED
532									
500						11	74	11	
400						16	73	23	
300						50	70	41	
						130	67	46	



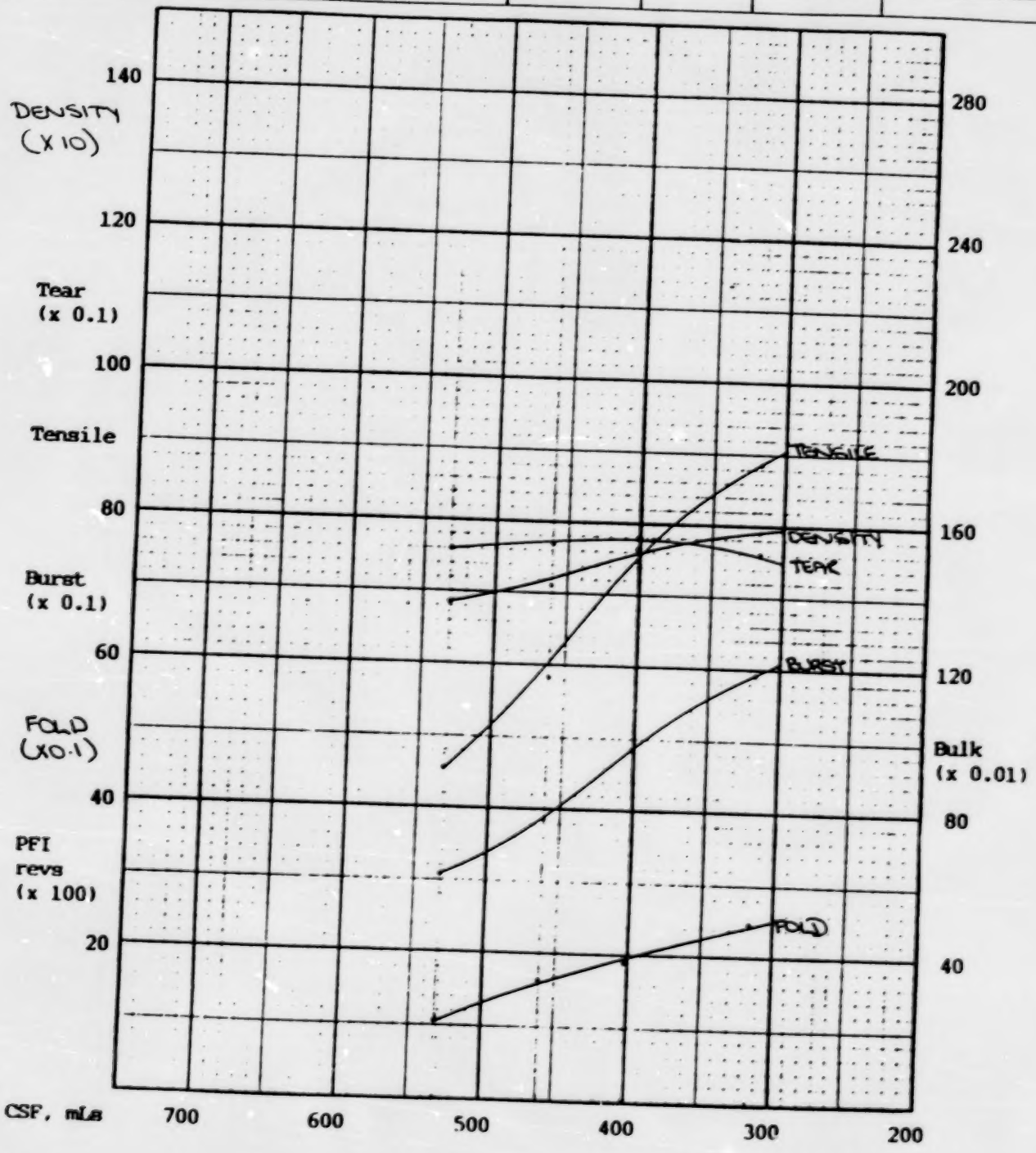
DSS ALBERTA 5702254 AP2-D BALSAM/BIRCH (METHANOL-COOKED) 14/08/87 SW

CSF mLs	PFI revs	BURST FACTOR	TEAR FACTOR	TENSILE m	BULK cc/g	POROSITY sec/100ml	OPACITY %	FOLD COUNT	VISCOSITY 0.5% CED
531	0	31	77	4700	1.46	13	74	11	
500	70	35	78	5300	1.43	18	72	24	
400	620	49	79	7700	1.33	66	70	88	
300	1530	64	76	9200	1.24	164	64	327	



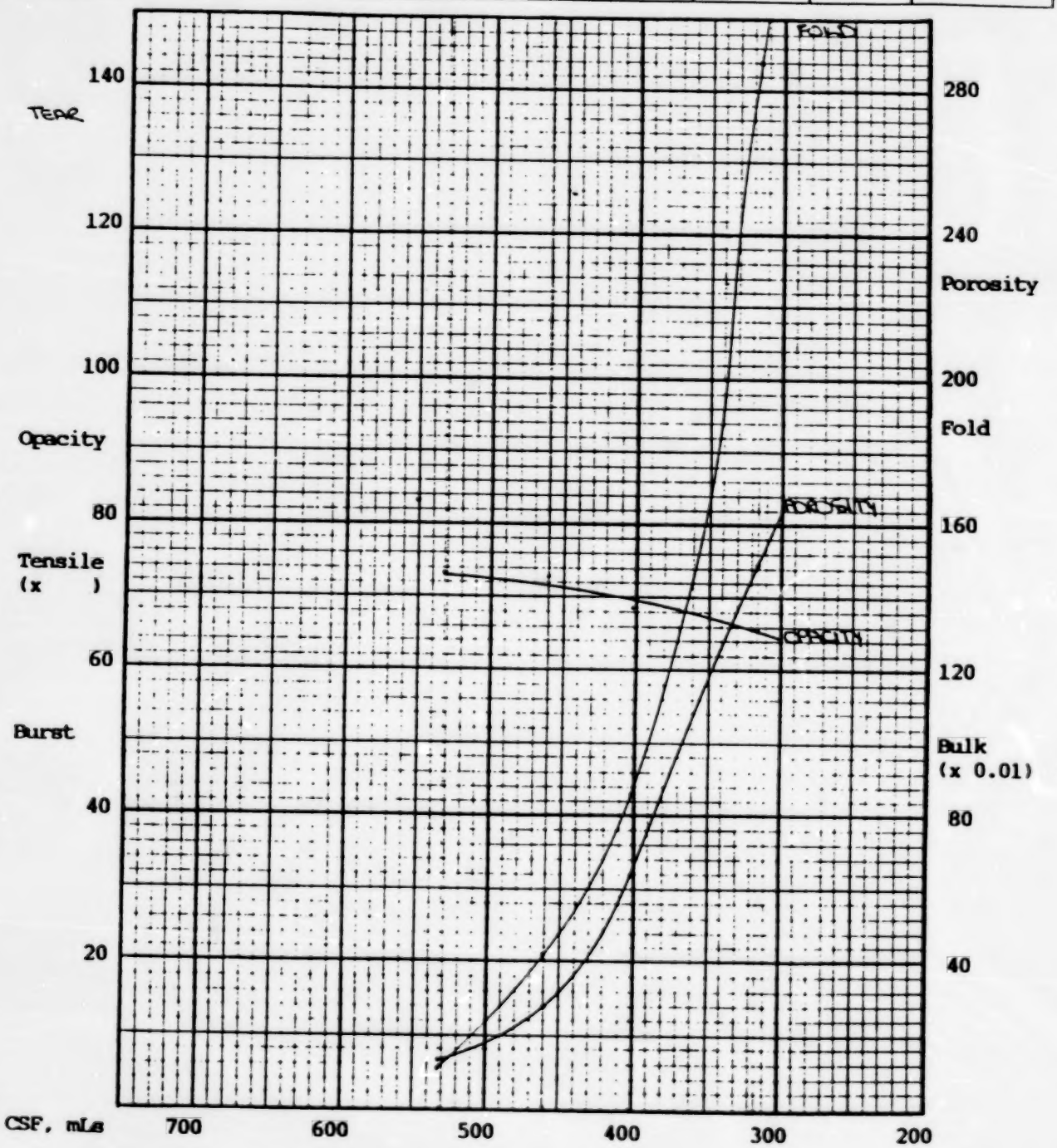
Dep ALBERTA 500 125 APA:D BALSAM/POPLAR (METHANOL COOKED) 14/08/21 SLW

CSF mLs	PFI revs	BURST INDEX kPa.m2/g	TEAR INDEX mN.m2/g	TENSILE N.m/g	DENSITY kg/m3	FOLD (LOG)	VISCOSITY 0.5% CED, cp
531		3.09	76	46	685	1.0	
500		3.40	77	52	700	1.3	
400		4.83	73	76	760	2.0	
300		6.07	75	91	800	2.5	



DSS ALBERTA 570 B4 — APD BALSAM/POPLAR (METHANOL COOKED) 14/08/87 SW

CSF mLs	PFI revs	BURST FACTOR	TEAR FACTOR	TENSILE m	BULK cc/g	POROSITY sec/100ml	OPACITY %	FOLD COUNT	VISCOSITY 0.5% CED
531						13	74	11	
500						18	72	24	
400						66	70	88	
300						164	64	337	



4. NEUTRAL SULPHITE SEMI-CHEMICAL (NSSC) PULPS

Hardwoods are frequently used as the base for corrugating medium prepared by the NSSC process.

Pulping conditions and results are given in Table 11. The yield of 77% is typical for this type of pulp and was chosen for that reason. Pulping proceeded satisfactorily.

Strength characteristics are detailed in Figures 19-22. The strength is compared with that from frequently used south eastern USA hardwoods in Table 12. This comparison shows that the aspen and balsam poplar give equivalent or superior strength relative to the more important burst and concora, compared with south eastern USA hardwoods.

Trembling aspen and balsam poplar would be suitable raw materials for corrugating medium production.

TABLE 11
NSSC PULPING CONDITIONS AND RESULTS

Cook number	L75-1	L75-3
Furnish	Aspen	Balsam Poplar
Chemical charge:		
Na_2SO_3, % as Na_2SO_3	12.0	12.0
Na_2CO_3, % as Na_2CO_3	5.0	5.0
L/W	5/1	5/1
Maximum temperature, °C	168	168
Time at maximum, minutes	90	90
Total yield, %	77.3	77.1
Total rejects, %	0.9	2.8
Initial pH of liquor	11.66	11.63
pH of spent liquor	6.85	7.22
Pulp viscosity, 0.5% CED, cp	105.7	123.3

Other conditions:

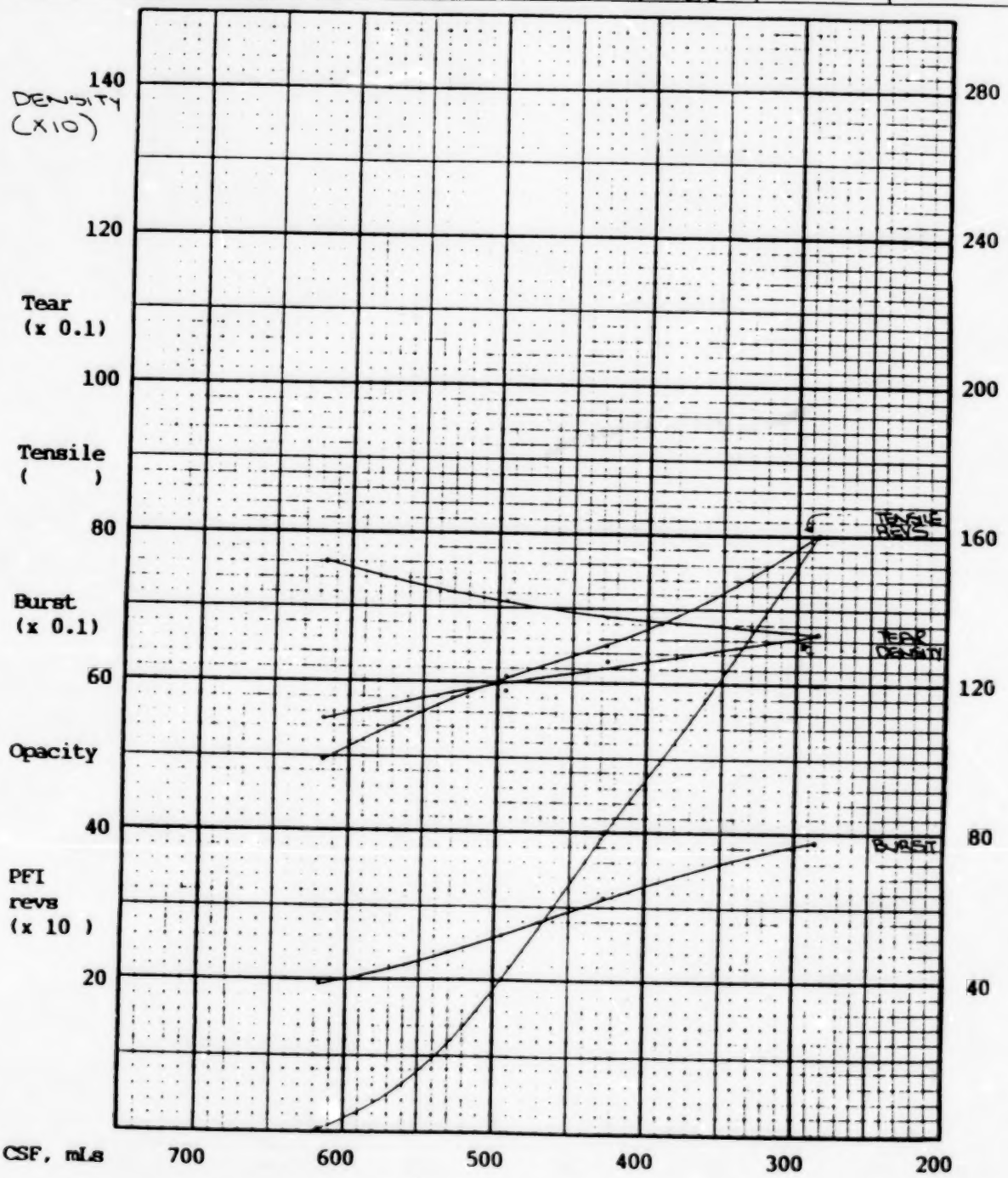
Presteaming for 3 minutes at atmospheric pressure
25 minutes from 90°C to 130°C
45 minutes at 130°C
30 minutes from 130°C to 168°C
Cooked chips hot refined at 0.050" and then at 0.020"
Pulps screened through 12 cut flat screen.

TABLE 12
COMPARISON OF NSSC ASPEN AND BALSAM POPLAR PULPS
WITH NSSC PULP FROM SOUTH EASTERN USA
(PFI DATA @ 400 CSF)

ANALYSES	Aspen	Balsam Poplar	Hardwood
Burst index, kPa.m²/g	3.28	4.02	2.75
Tear index, mN.m²/g	6.8	6.7	8.0
Tensile index, N.m/g	67	77	67
Density, kg/m³	630	670	476
Concora, N	351	418	364

DSS ALBERTA 57W34 L75-1 ASPEN NSSL 30/07/47

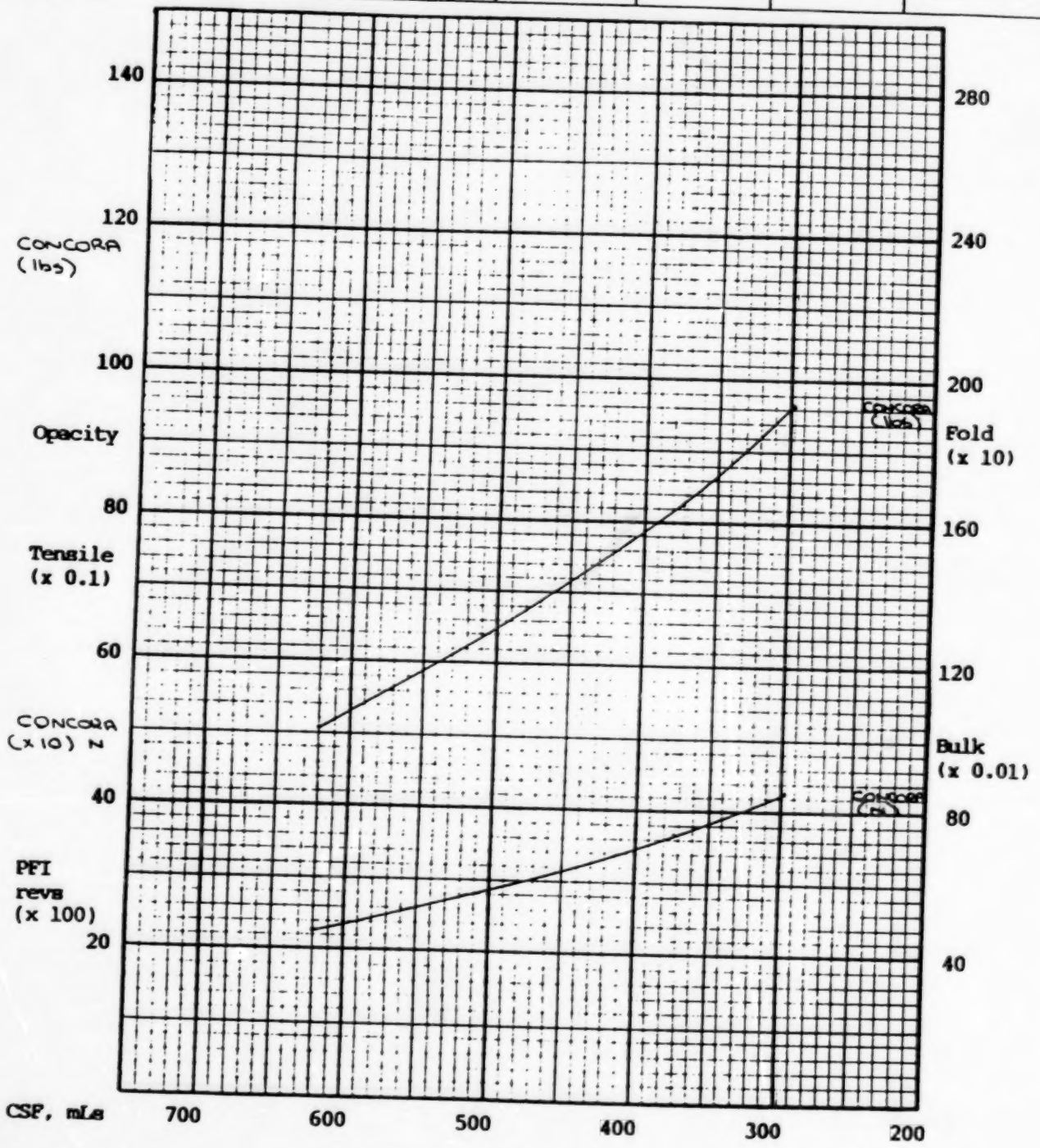
CSF mLs	PFI revs	BURST INDEX kPa.m2/g	TEAR INDEX mN.m2/g	TENSILE INDEX N.m/g	DENSITY kg/m3	OPACITY %	VISCOSITY 0.5% CED, cp
616	0	199	76	50	550		
600	20	2.00	75	51	560		
500	190	2.60	71	60	600		
400	470	3.28	69	67	630		
300	760	3.52	67	78	660		



ECONOTECH

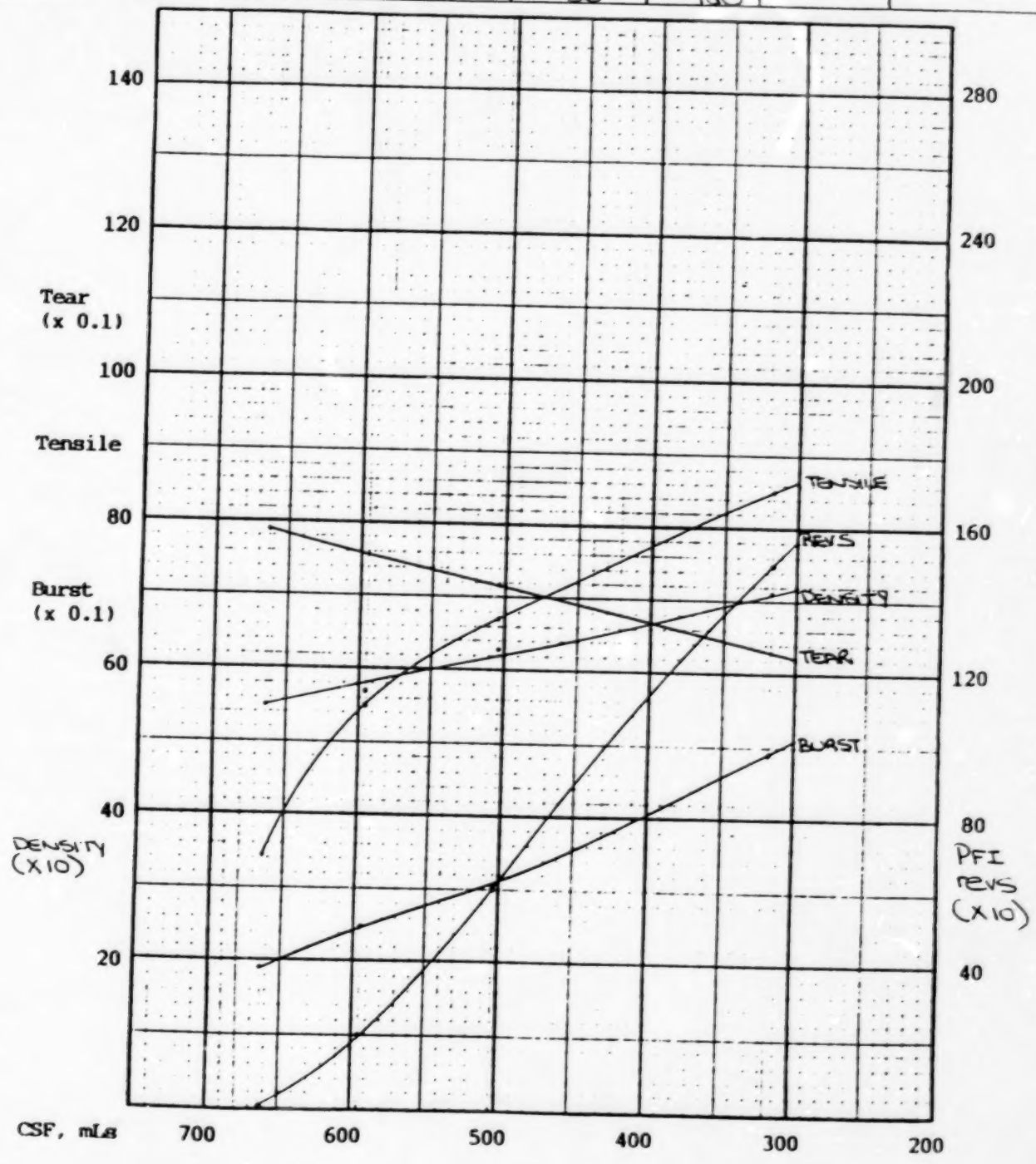
DSS ALBERTA 5710034 L75-1 ASPEN NSSC 14/08/87SA

CSP mLs	PFI revs	CONCORA (lbs)	CONCORA (N)	TENSILE km	BULK cc/g	OPACITY %	VISCOSITY 0.5% CED
620		50	224				
600		53	240				
500		65	290				
400		79	350				
300		96	420				



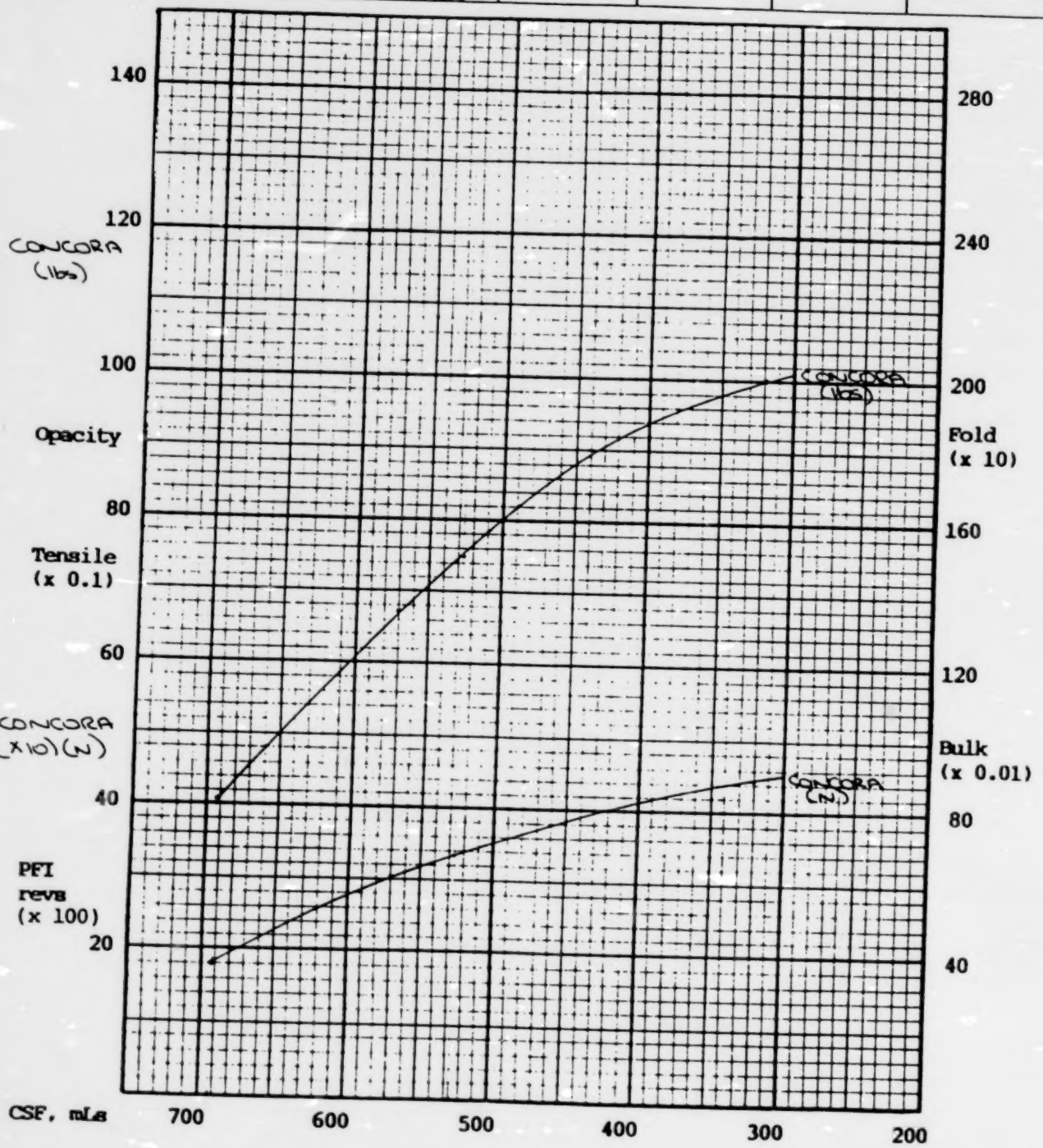
D&D ALBERTA 570034 L75-3 BALSAM/KRAFT NSSC 30/07/97 SW

CSF mLs	PFI revs	BURST INDEX kPa.m2/g	TEAR INDEX mN.m2/g	TENSILE INDEX N.M/g	DENSITY kg/m3		VISCOSITY 0.5% CED, cp
663	0	1.92	79	34	550		
600	190	2.40	76	54	580		
500	620	3.10	7.1	68	620		
400	1130	4.02	67	77	670		
300	1520	5.10	62	96	720		



DSS ALBERTA 570039 L75-3 BALSAM/POPLAR NSSC 14/08/87SW

CSF mLs	PFI revs	CONCORA (lbs)	CONCORA (N)	TENSILE km	BULK cc/g	OPACITY %	VISCOSITY 0.5% CED
643		41	180				
600		61	280				
500		80	350				
400		94	410				
300		101	450				



5. HIGH YIELD SULPHITE

A high yield sulphite pulp with its attendant high brightness could be used in newsprint.

Pulping conditions and results with this process are given in Table 13. The unbleached pulp is high yield and brightness. The pulps were readily bleached by a mild peroxide treatment to news brightness (see Table 14). Strength characteristics are given in Figures 23-29 and show that, depending on overall cost, this pulp could act as a component of newsprint or other papers.

TABLE 13
HIGH YIELD SULPHITE PULPING CONDITIONS AND RESULTS

Cook number	A1934	A1935
Furnish	Aspen	Balsam Poplar
Chemical charge:		
SO_2 to give 4.5 pH		
NaOH, % on o.d. wood	6.2	6.2
L/W	5/1	5/1
Maximum temperature, °C	155	155
Time to max temp, min	120	120
Time at max temp, min	90	90
Total yield, %	66.0	75.5
Total rejects, %	0.8	5.3
Initial pH of liquor	4.5	4.5
pH of spent liquor	3.2	3.9
Kappa number	57.5	85.7
Brightness, Elrepho	52.4	50.6

Other conditions:
Presteaming: 10 minutes @ atm pressure, 100°C
Cooked chips refined @ 0.050" S/W and then @ 0.020" S/W
Cooking liquor: pH adjusted to 4.5 with SO_2

TABLE 14
BLEACHING OF HIGH YIELD SULPHITE TO NEWS BRIGHTNESS

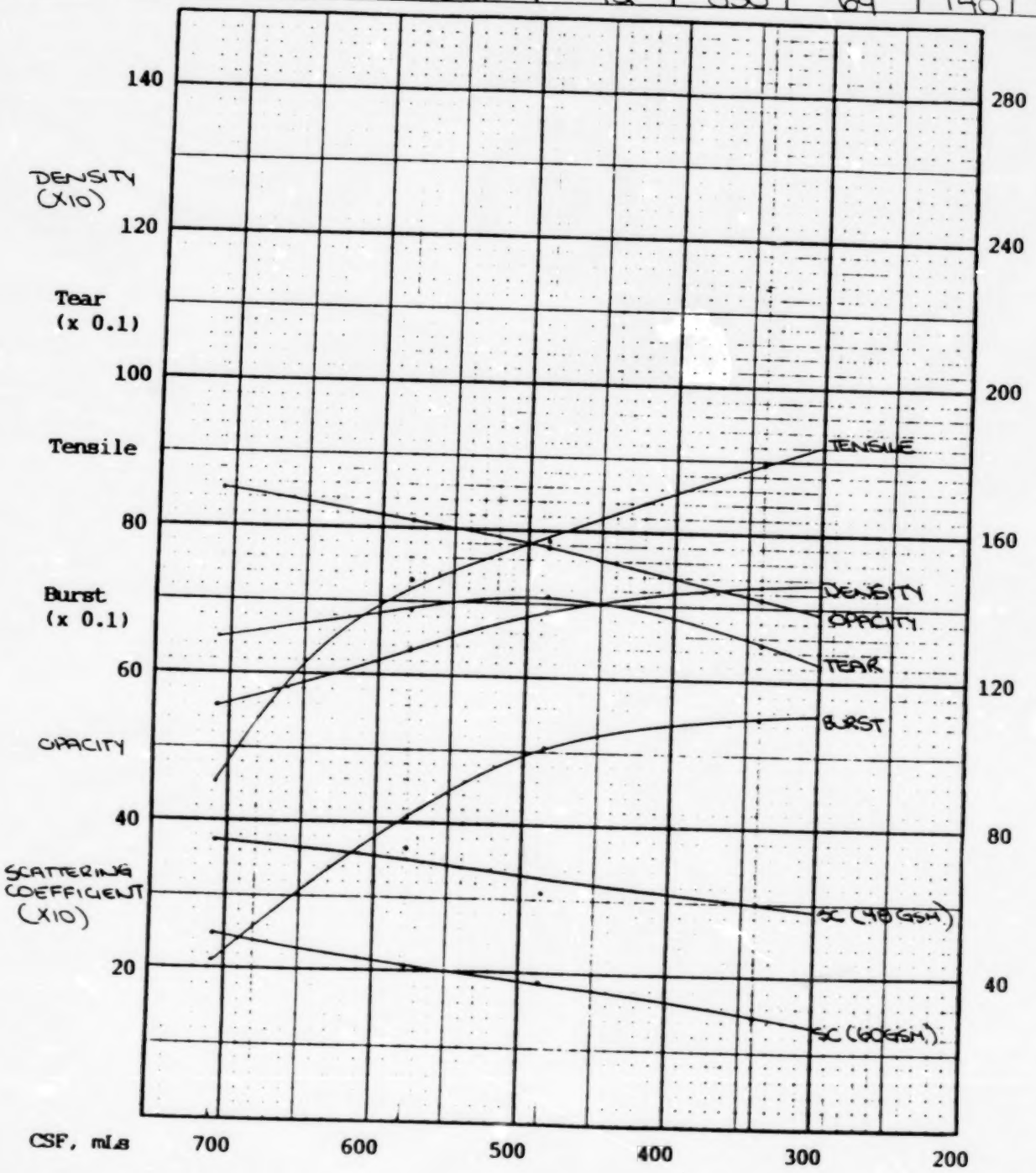
Cook number	A1934	A1935
Furnish	Aspen	Balsam Poplar
H_2O_2 on pulp, %	1	1
Time, minutes	90	90
Temperature, °C	60	60
Initial pH	10.95	10.91
Final pH	8.00	8.19
Initial brightness, TAPPI, Elrepho	52.4	50.6
Final brightness, TAPPI, Elrepho	62.2	58.6

Other conditions:

0.05% epsom salts
2.0% silicate
0.5% DTPA
1.23% total alkali as NaOH

DSS ALBERTA 570039 A-1434 ASPEN (SULFITE HIGH YIELD) 14/08/87SW

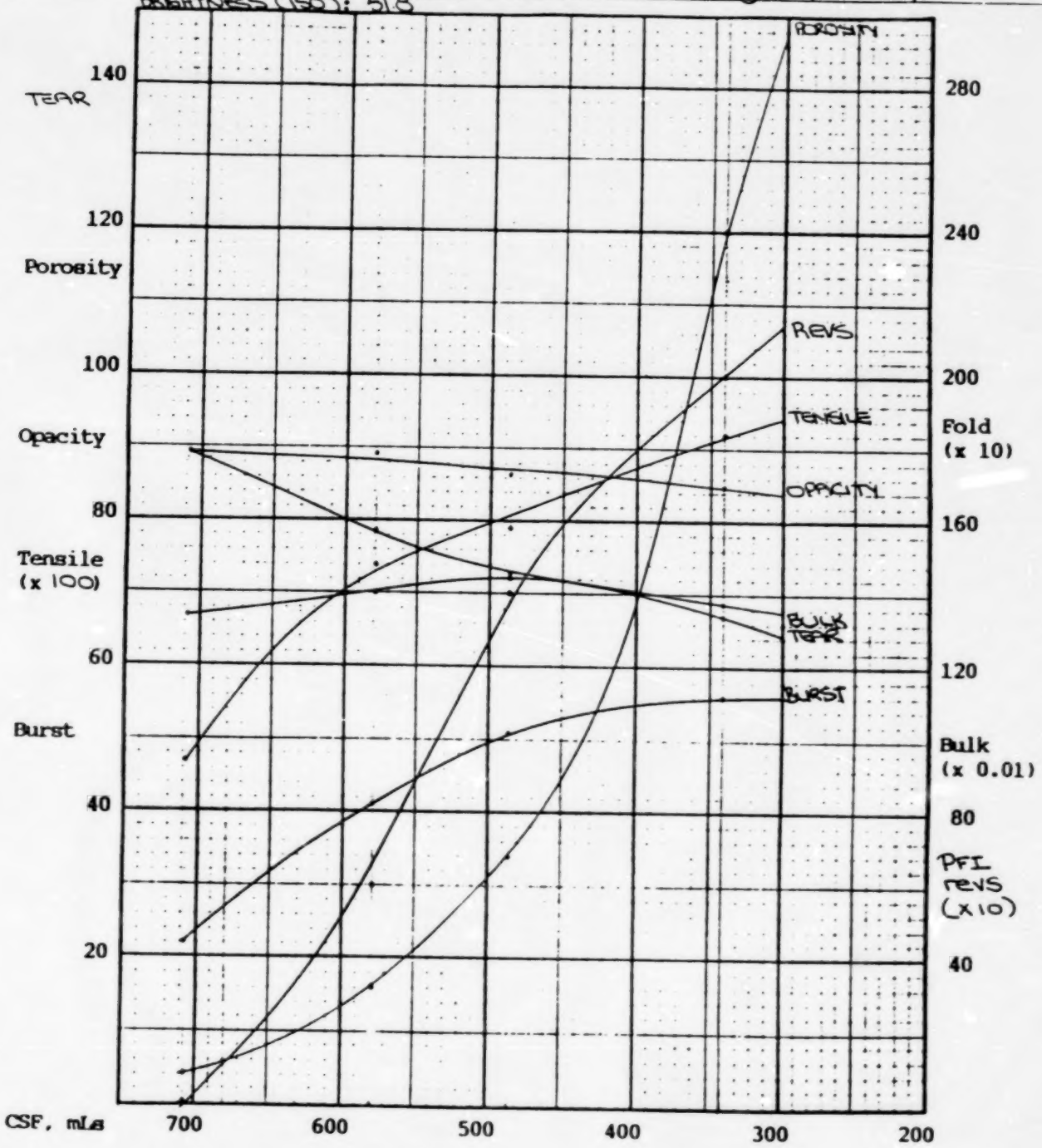
CSP mLs	PFI revs	BURST INDEX kPa.m2/g	TEAR INDEX mN.m2/g	TENSILE N.m/g	DENSITY Kg/m3	OPACITY % (48GSM)	SCATTERING COEFFICIENT (Kg/m²) 60GSM	48GSM
708		2.13	6.5	46	560	86	249	377
600		3.80	6.8	69	620	82	220	360
500		4.97	7.1	78	680	78	190	330
400		5.40	6.8	86	720	74	170	310
300		5.58	6.2	92	830	69	140	240



D55 ALBERTA 5700734 A-1934 ASPEN (SULFITE HIGH YIELD) 14/08/37 SW

CSF mLs	PFI revs	BURST FACTOR	TEAR FACTOR	TENSILE m	BULK cc/g	POROSITY sec/100ml	OPACITY (60gsm) %	FOLD COUNT	VISCOSITY 0.5% CED
708	0	32	67	4700	1.79	4	89		
600	520	38	70	7000	1.60	13	88		
500	1270	50	72	8000	1.48	31	97		
400	1800	55	70	8800	1.41	69	96		
300	2140	56	64	9400	1.36	148	84		

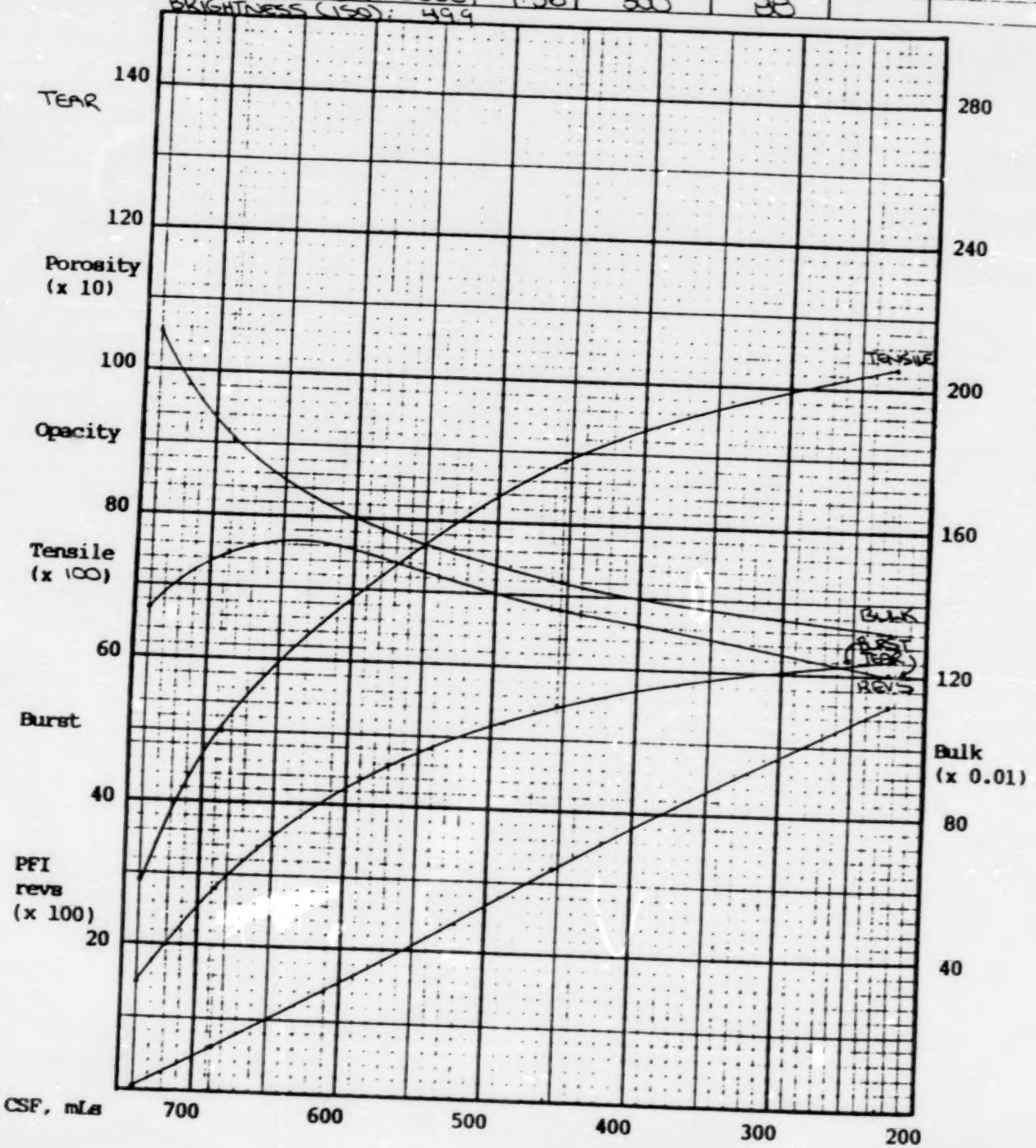
BRIGHTNESS (ISO): 51.8



DSS ALBERTA 5700334 A-1935 BALSAM/POPLAR (SULFITE HIGH YIELD) 14/08/87SW

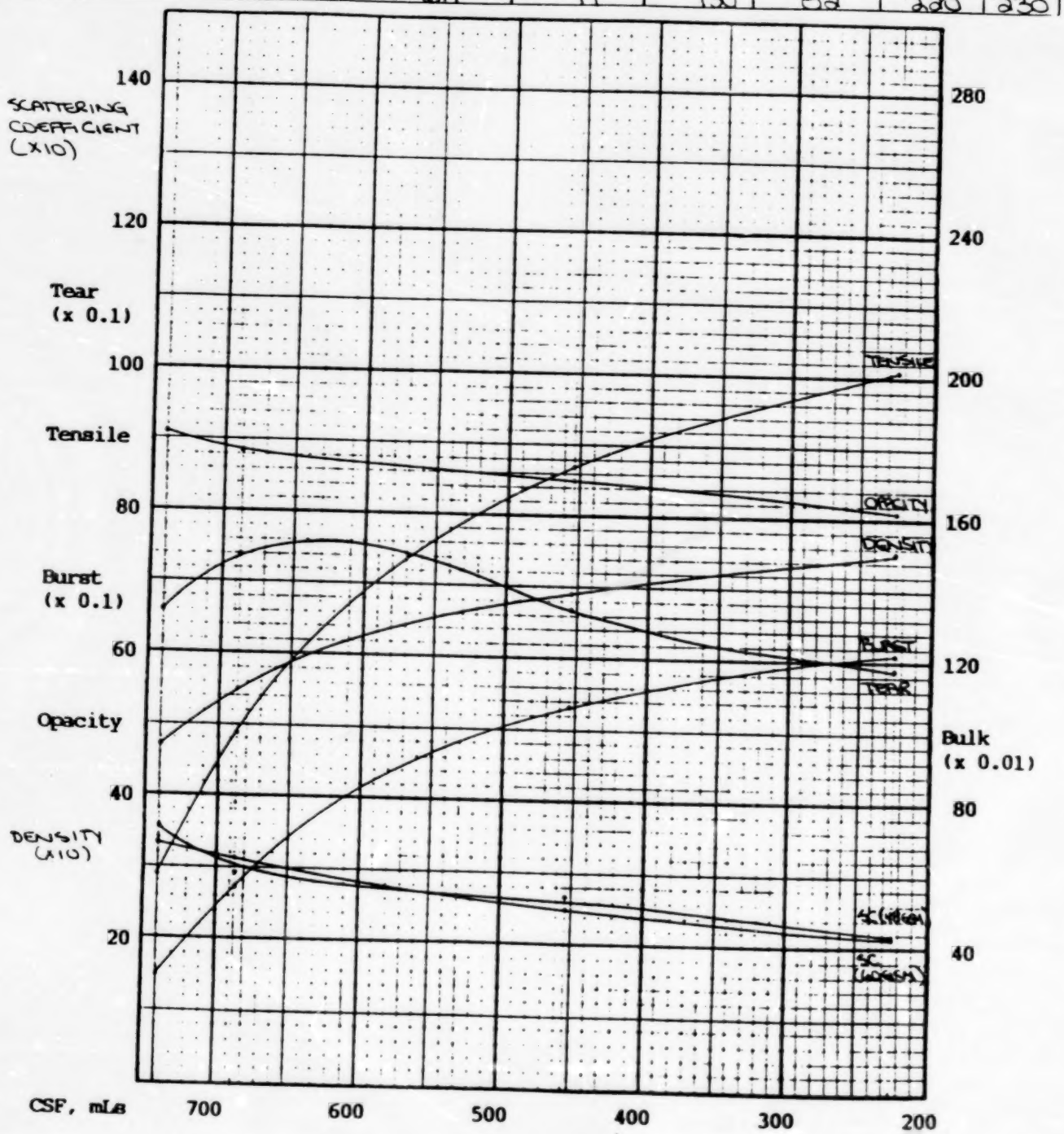
CSF mLs	PFI revs	BURST FACTOR	TEAR FACTOR	TENSILE m	BULK cc/g	POROSITY sec/100ml	OPACITY %	FOLD COUNT	VISCOSITY 0.5% CED
740	0	15	67	2900	2.11	1	94		
600	11600	42	76	6400	1.60	10	92		
500	21600	52	70	8400	1.48	20	90		
400	32800	57	66	9400	1.40	100	89		
300	42800	60	63	10000	1.36	300	88		

BRIGHTNESS (ISO): 49.9



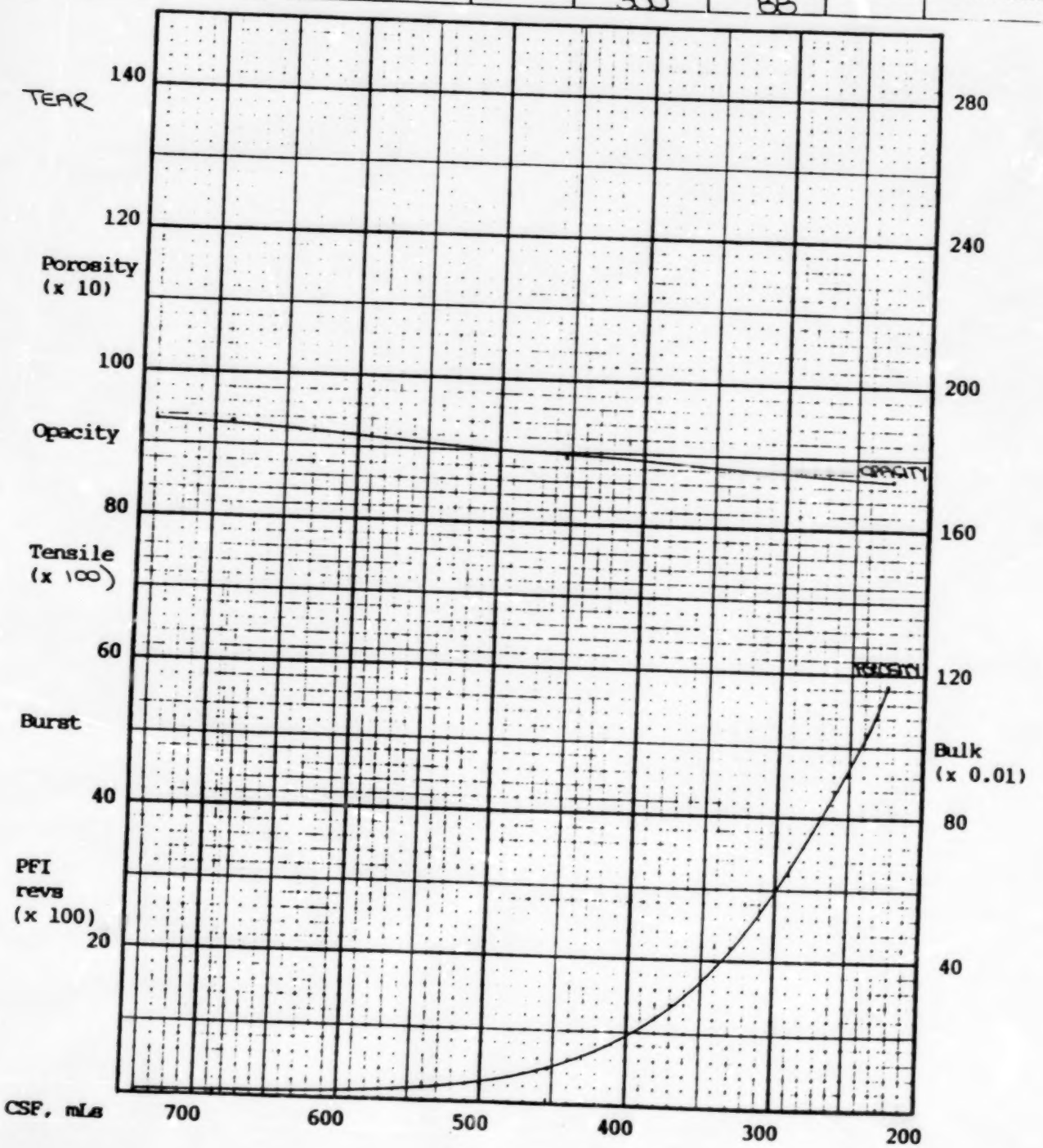
D55 ALBERTA 970234 A-1935 BALSAM/POPLAR (SULFITE HIGH YIELD) 14/08/97 SLO

CSF mLs	PFI revs	BURST INDEX kPa.m2/g	TEAR INDEX mN.m2/g	TENSILE N. m/g	DENSITY Kg/m3	OPACITY 418GSM %	SCATTERING COEFFICIENT (m2/kg) 600GSM	418GSM
740		1.48	66	29	494	91	335	354
600		4.17	7.6	69	630	87	280	320
500		5.03	7.0	82	680	86	260	270
400		5.59	6.4	91	710	84	240	260
300		5.91	6.1	97	730	82	220	230



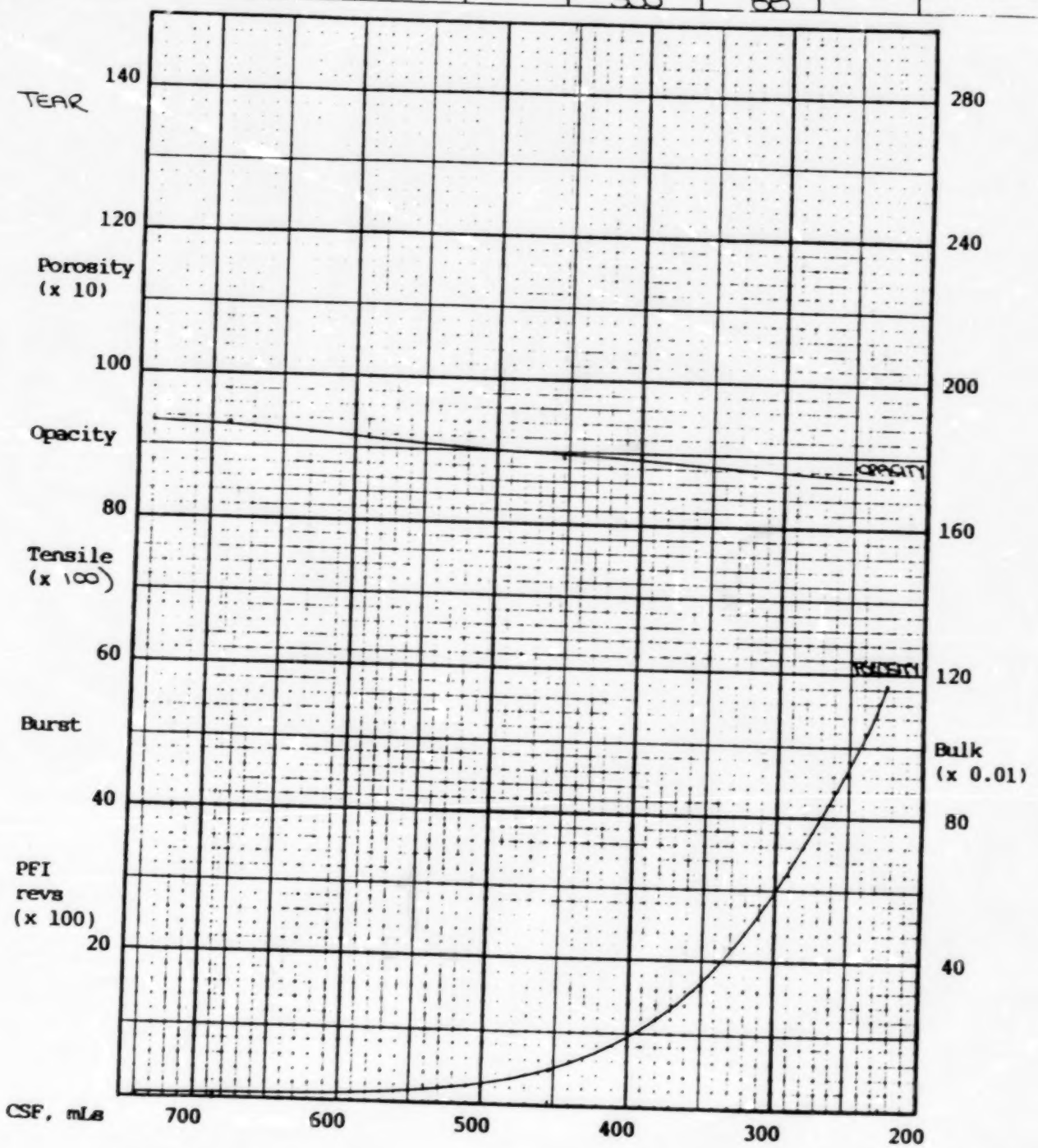
DDS ALBERTA 5710039 A1436 BALSAM/POPLAR (SULFITE HIGH YIELD) 14/08/87 SM

CSF mLs	PFI revs	BURST FACTOR	TEAR FACTOR	TENSILE m	BULK cc/g	POROSITY sec/100ml	OPACITY 400nm %	FOLD COUNT	VISCOSITY 0.5% CED
740						1	94		
600						10	92		
500						20	90		
400						100	87		
300						300	88		



DDS ALBERTA 5700.34 A1435 BALSAM/POPLAR (SULFITE HIGH YIELD) 14 lbs/ton SAT

CSF mLs	PFI revs	BURST FACTOR	TEAR FACTOR	TENSILE m	BULK cc/g	POROSITY sec/100ml	OPACITY (GOUGH) %	FOLD COUNT	VISCOSITY 0.5% CED
740						1	94		
600						10	92		
500						20	90		
400						100	89		
300						300	88		



6. CTMP

The wood chips from each furnish were processed separately by a two component impregnation treatment to attain good bonding properties with reasonable opacity and scattering coefficient.

Pretreatment included a 5 minute hot distilled water chip wash followed by pressurized steaming for 15 minutes. Chemical impregnation was done using 5% sodium hydroxide and 2% sodium sulphite at atmospheric pressure, 50°C for 35 minutes. The impregnated wood chips were compressed to yield approximately 45% o.d. and then retained at 50°C for 25 minutes prior to refining. The production data appears in Table 15.

A Sprout-Waldron, model 105-A, 12" single rotating disc laboratory refiner equipped with screw feeder and D2B505 refiner plates was utilized to yield three levels of drainage between 300 and 100 mLs C.S. freeness.

The samples were pretreated with 0.5% DTPA at pH 7 prior to bleaching. The balsam poplar pulp contained more ion contamination than the aspen. Peroxide bleaching for 4 hours at 10% consistency at 60°C with 0.05% $MgSO_4$ and 3.5% sodium silicate was carried out. Refining and bleaching

data appear in Table 16. It should be remembered that the basic wood brightness was lower for balsam poplar (see Table 1).

Table 17 displays the physical and optical properties of the resulting CTMP's. Handsheets and the analysis were according to TAPPI standards or manufacturers procedures. Both pulps exhibited good bonding properties.

Table 18 compares key properties of the aspen and balsam poplar with eucalyptus globulus and saligna at a drainage level of approximately 100 mLs C.S. freeness. Both the aspen and balsam poplar were more dense, had superior tear and tensile properties with equivalent opacities compared to the eucalyptus samples. There was some loss in the scattering coefficient, particularly the aspen, and in brightness gain for the aspen and balsam poplar compared to the eucalyptus. This may in part be due to the peroxide application. The initial aspen brightness was the lowest of all samples but had a reasonable gain with bleaching. It should be noted that the aspen wood brightness was 62.6 and the balsam poplar wood brightness was 54.1 (see Table 15). As the primary concern was for bonding properties and not optical properties, ion contamination was not monitored during pretreatment and refining. The high caustic chemical

application would appear to affect aspen the greatest as evidenced by the wood brightness and unbleached brightness.

Considerable other work has been carried out on trembling aspen CTMP and on mixtures with softwoods. Much of this has been done by Sunds Defibrator. Mixtures can be tailored to give high quality pulps for tissue and printing/writing papers with limitations partially dependent on CTMP brightness.

The softwood gives high strength and low fines and the hardwood gives high opacity. Bleached CTMP from aspen or balsam poplar (or mixtures with, for example, spruce) can replace some of the hardwood kraft pulp in fine papers where brightness is below 80.

TABLE 15
CTMP PRODUCTION DATA

	R261			R263		
Furnish (-7/8 +3/16)	Aspen			Balsam Poplar		
Wood brightness	62.6			54.1		
Pretreatment						
Chip wash, hot d H_2O 75-80°C, min	5			5		
Presteam, pressurized, psig	51-52			51-52		
Time, min	15			15		
Impregnation, atmospheric						
Chemical application, NaOH, %	5			5		
Na_2SO_3, %	2			2		
pH, as found	13.61			13.64		
Time, min	35			35		
Temperature, °C, initial	49			45		
final	70			68		
Compression						
Time, min:sec	1:28			1:22		
Pressing force, tons	30			40		
O.D. content, %	41.6			45.0		
Retention Period						
Time, min	25			25		
Temperature, °C, initial	55			56		
final	49			48		
Refining Data						
First pass yield, %	94.1			94.5		
Refiner pass number	2	3	3	2	3	4
C.S. freeness, mLs	259	180	92	285	220	120

TABLE 16
BLEACHING DATA

Species	--- Balsam Poplar---			-- Trembling Aspen --		
Freeness	260	200	101	240	161	79
Bleaching, 4% H_2O_2						
Total alkali, %	2.9	2.9	2.9	3.3	3.3	3.3
Final pH	10.0	10.0	10.1	9.8	9.7	9.8
Residual, % of applied	39.0	37.2	37.2	47.8	45.9	44.4
Consumption, %	2.44	2.51	2.51	2.09	2.16	2.23
Ion contaminants before pretreatment with 0.5% DTPA at pH 7						
Mn, ppm	11	10	11	4.1	4.7	4.4
Cu, ppm	15	12	26	7.2	19	20
Fe, ppm	83	84	96	56	83	71
Ion contaminants after pretreatment						
Mn, ppm	5.5	5	4.4	1.4	1.3	1.3
Cu, ppm	14	8.4	12	5.9	11	9.2
Fe, ppm	87	79	92	58	75	72
Brightness, T525, %						
Initial	39.0	41.3	37.8	46.0	45.5	45.7
Final	62.8	63.4	61.5	68.3	68.0	66.6
Change	23.3	22.1	23.7	22.3	22.5	20.9

Standard conditions for bleaching:

Time, hours	4
Consistency, %	10
Temperature, °C	60
$MgSO_4$, %	0.05
Sodium silicate, %	3.5

TABLE 17
BLEACHED HANDSHEET PROPERTIES

	--- Trembling Aspen --			-- Balsam Poplar ---		
Handsheet Properties:						
C.S. freeness, mLs	240	161	79	260	200	101
Drainage, sec	7.7	12.7	27.9	6.6	8.9	15.8
Density, kg/m³	563	585	645	505	538	583
Bulk, cc/g	1.78	1.71	1.55	1.98	1.86	1.72
Burst factor	27	30	37	20	22	27
Burst index, kPa.m²/g	2.65	2.96	3.61	2.01	2.15	2.62
Tear factor	72	70	67	72	70	69
Tear index, mN.m²/g	7.08	6.87	6.61	7.03	6.85	6.77
Tensile, m	5562	6115	7557	4565	4992	5816
Tensile index, N.m/g	55.6	60.0	74.1	44.8	49.0	57.0
Opacity, T519, %	79.6	80.3	79.8	85.9	87.0	87.5
Scattering coeff, m²/kg	33.8	34.4	32.1	40.8	42.0	43.0
Absorption coeff, m²/kg	0.71	0.77	0.76	1.20	1.26	1.29
Porosity, Gurley, sec/100ml	396	1015	3676	100	201	773
Pulp Properties:						
Pulmac rejects, %						
0.006"	0.41	0.20	0.02	0.18	0.04	0.01
0.004"	9.6	6.0	2.2	8.6	5.0	1.42

TABLE 18
BLEACHED CTMP COMPARATIVE DATA

	Aspen	Balsam Poplar	---Eucalyptus*--- Globulus	Saligna
C.S. freeness, mLs	79	101	86	102
Density, kg/m³	645	583	522	445
Tear index, mN.m²/g	6.6	6.8	6.1	5.0
Tensile index, N.m/g	74.1	57.0	50.7	41.2
Opacity, T519, %	79.8	87.5	79.5	85.0
Scattering coeff, m²/kg	32.1	43.0	42	47
Brightness, %				
Initial	37.8	45.7	53.6	42.6
Bleached	61.5**	66.6**	81.1	77.1
Gain	23.7	20.9	27.5	34.5

*conditions for pretreatment, refining and bleaching are the same for all pulps with the exception of H_2O_2 applied for eucalyptus, which was 4.5%.

**pulping was designed to give high strength. A brightness of 80 can be achieved at higher yield/lower strength.

CONCLUSIONS

1. Balsam poplar gave higher strength paper products than aspen, but slightly lower pulping yields.

2. Compared with softwoods the two hardwoods gave higher pulping yields than typical softwoods and gave lower K numbers into the bleach plant which would give reduced environmental impact. In general, chemical requirements for the hardwoods were lower than for softwoods.

3. In comparison with widely accepted eucalyptus raw material, aspen and balsam poplar gave kraft pulp of higher yield but somewhat lower strength. These kraft pulps bleached very readily by the short sequence D/CEoD which represents a significant capital advantage over softwoods. The balsam poplar kraft pulp was significantly higher in strength and that from the trembling aspen.

4. Alkaline sulphite/anthraquinone (ASAQ) pulping gave higher yield than kraft but lower yield in the bleaching stages. Overall yield was similar to kraft. The pulp bleached very readily to high brightness and gave higher strength than kraft at the high freeness levels.

5. Solvent pulping using methanol gave equivalent overall yields to kraft and also bleached to 90 brightness with short sequence bleaching. At the higher freeness levels, strengths were superior to kraft except for a somewhat lower tearing strength.

6. Trembling aspen and balsam poplar would make satisfactory corrugating medium by the NSSC process.

7. High yield sulphite pulping yielded pulps at good yield and brightness. With a mild peroxide treatment newsprint brightness was produced.

8. Chemithermomechanical pulping (CTMP) of aspen and balsam poplar confirmed the potential of this was process which is well documented in the literature.